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A Course on Troubleshooting O and M Problems in Wastewater Treatment Facilities - Instructor Notebook

American Public Works Association, Chicago, Ill

Prepared for

National Training and Operational Technology Center, Cincinnati, Ohio

Aug 76

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40- hour course materials are available on free loan basis to educational institutions as well as personnel of private and public sector wastewater treatment facilities.

16. ABSTRACT

This Instructor Manual, together with the referenced Student Manual is designed for use by instructors who wish to teach a short-term education/training course on the process of troubleshooting operation and maintenance problems in wastewater treatment plants. These materials are geared toward procedures for identifying and isolating a problem, formulating alternative actions and solutions, and combining corrective action withshort and long-range followup. The materials will assist state, local and Federal employees of wastewater facilities in assuming and administering their responsibilities and preparing for O&M inspections. Some topics included are activated sludge, flow measurement, lab procedures, chlorine and solids handling.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
wastewater, wastewater treatment, oxidation lagoons, activated sludge, solids handling, performance evaluations, inspections	troubleshooting, problem solving, operations, maintenance, process control	5I 13B

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A COURSE ON

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

INSTRUCTOR NOTEBOOK

August 1976

This course was developed by the American Public Works Association in cooperation with the Municipal Operations Branch of the U.S. Environmental Protection Agency under Grant No. T 900535-01-0

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MEMORANDUM

TO: Course Director
FROM: Course Developers (American Public Works Association)
SUBJECT: Instructions for the presentation of the Troubleshooting Course
DATE: August 31, 1976

The purpose of this memorandum is to provide you, the Course Director, with instructions, guidelines, and general information on the staging of the course, Troubleshooting O&M Problems in Wastewater Treatment Facilities. The course developers hope that the following information will be helpful.

I. *Origin, Philosophy and Background of the Course*

This course grew out of the concerns of the Municipal Operations Branch of the U.S. Environmental Protection Agency for the performance of the thousands of wastewater treatment facilities in which this nation has invested billions of dollars.

Early in 1975, EPA asked the American Public Works Association to develop and test an education/training program which would assist employees of state or federal water pollution control agencies with their responsibilities for wastewater treatment plant inspections. Since many of the inspectors were familiar with conducting performance evaluations and in some instances providing technical assistance, it was mutually agreed that the *Process of Troubleshooting* would be the basis for and overriding philosophy of a short-term intensive education/training course. (The Process of Troubleshooting is the procedure for identifying and isolating a problem, formulating alternative actions and solutions, and combining corrective action with short- and long-range follow-up.) The development of the course was overseen by a Technical Review Committee established by EPA for that purpose.

During the development of the course, it was determined that the prospective student for this course should have a B.S. in Engineering or its equivalent in training and experience. Further it was agreed that students will gain most from the course if they have a full prior understanding of the operation and maintenance of wastewater treatment facilities.

USEPA's objectives in supporting the development of this course are best described in the following statements on expected student outcomes. As a result of this course, students will be able to:

A. Perform an adequate evaluation of the performance of a treatment facility.

B. Determine what information must be obtained to define corrective actions to improve wastewater treatment plant performance.

C. Identify the problems that cause inadequate performance, and assign the causes among such factors as operation, maintenance, loading, process control procedures and strategy, design, and other functions.

D. Analyze available data to determine corrective procedures most likely to be effective in particular situations, and implement those procedures to improve treatment plant operations.

E. Maintain liaison among federal, state, and municipal jurisdictions on the progress, intent, and limitations of inspection and technical assistance programs and,

F. Organize and present a course to train inspection personnel and plant operators in troubleshooting skills so that agencies will be able to maintain and expand their program capability.

Prior to its completion and distribution in its present form, this course underwent trial presentations in seven EPA Regions, from August 1975 through May, 1976. The present form of the course reflects much of what was learned during these trial runs toward polishing and improving the course materials.

II. *Educational Approach*

Because the key to successful troubleshooting and technical assistance is the working relationship between the troubleshooter and the plant operator, this course stresses human (interpersonal) skills as well as technical skills.

The Course Director should note that the teaching-learning rational of *adult education* is reflected throughout this course. In the trial presentations of this course it was demonstrated that students with the prescribed entry background have much to contribute to each other, by virtue of their experience in inspecting wastewater treatment plants. Therefore, the course employs various adult education techniques because adults bring a great deal of insight and information to any given learning situation, and it is important to provide opportunities for the students to learn from each other as well as from the instructor "expert."

This course is built upon a variety of educational techniques to assist in the development of both behavioral and technical skills. As Course Director you will find that case study problem situations are explored by means of lectures, discussions, visuals, record analysis, role playing, simulation games, quizzes, and small group interaction techniques. Problem solving is at the heart of most of the lesson approaches. It should be recognized also that potential students for this course are accustomed to a rather highly charged working environment in the field versus a staid classroom setting; and therefore, simulation and participatory activities along with project and case studies help to keep the learning situations from "bogging down" and prevent the students from losing interest.

III. *Responsibilities of the Course Director*

This course generally requires from 30 to 40 hours for a complete presentation. The principal responsibilities of the Course Director are *preparation and continuity*. It is important that one individual – designated as Course Director – be given the responsiblity to coordinate the considerable amount of preparation required as well as serve as on-site director during the presentation of the course. The principal responsibilities of the Course Director include:

A. Scheduling the course
B. Screening and selecting students, and making necessary arrangements for students to attend the course
C. Recruiting (hiring) and briefing instructors
D. Preparation of classroom and teaching facilities
E. Preparation and distribution of course materials
F. Teaching of Lesson 1 – Overview, and Lesson 2 – Elements of Troubleshooting. (In many instances, the Course Director would be the preferable instructor for these lessons.)
G. Maintain continuity throughout the course, from start to finish

IV. *Options for Scheduling*

The Course Director will note that the total course is arranged in a modular format of 12 volumes designed to promote flexibility in meeting the needs of various geographical regions as well as the availability of time which a particular group of students has to participate in in-service education and training activities. This format permits the presentation of the total course (or whatever components will comprise a total course for a given region) on an intensive four or five day, one week basis; or the course can be organized and run on one day per week for four or five weeks, or even one-half day per week for 8 – 10 weeks, depending upon the ease or difficulty of maintaining a class gathering for given time periods. Because the course contains a concentrated level of educational material, it is recommended that no more than 7 hours of class time be given in any one day.

The course materials contain 14 lesson segments, packaged in 12 volumes. Each segment, the volume, and the recommended length of time is listed below.

Lesson Segment	Volume	Recommended Time
Overview (OV)	1	3 Hours
Elements of Troubleshooting (ET)	1	1½ Hours
Pre/Primary Treatment (PR)	2	1¾ Hours
Trickling Filters (TF)	3	2 Hours
Oxidation Lagoons (OL)	4	1¾ Hours
Laboratory Practices (LP)	5	1½ Hours
Flow Measurement (FM)	6	1 Hour
Chemical Additions (CA)	7	1 Hour
Management Behavior (MB)	8	2 Hours
Activated Sludge (AS)	9	7¼ Hours
Solids Handling (SH)	10	5¾ Hours
Land Treatment (LT)	11	2 Hours
Chlorination (CH)	12	1½ Hours
Closing (CL)	1	1 Hour

TOTAL RECOMMENDED COURSE TIME 33 HOURS

Volume 2 through 12 each contain a lesson geared toward troubleshooting a particular treatment process (i.e., Pre/Primary treatment in Volume 2). Each volume also contains lesson materials on the Overview and Elements of Troubleshooting, which will serve as background material to make each volume a self-standing module. Volume 1 (i.e., volume in which this memorandum is placed) contains the full lessons, aids, and materials for the Overview, Elements of Troubleshooting and Closing topics.

Thus, at the Course Director's discretion, a course can be made longer or shorter depending upon the number of volumes or modules the Course Director feels should be included in the total learning experience. The various modules can also be used as refresher courses on certain treatment processes if that is desired. Each volume contains a discussion on options that the Course Director may follow in modifying the lesson, modifications which may affect the determination of a schedule for presenting the course.

V. *Selecting Students*

Because this course is designed around student participation, it is important that students selected for the course have the proper background so that they may both benefit from, and contribute to, the course presentation. The course was designed to enable state and federal agency field staffs to provide technical assistance to the operators of wastewater treatment plants – so it is those personnel who should be the prime candidates for taking this course.

The following entry level behavior is prescribed for students to whom this course is presented. Students will have had University training in Sanitary Engineering, waste treatment and/or related sciences or equivalent in experience and training. Some field experience in inspecting treatment plants, but none in operating waste treatment facilities.

As a prerequisite to this course, it is recommended that the student will be able to –

1. Identify treatment plant process units
2. Describe treatment plant process units and equipment in technical terms
3. Identify and explain the purpose of components of treatment plant process units, how they work and why they are important to the overall process
4. Describe the normal operating procedures for treatment plant process unit components
5. Identify when treatment plant process units are not operating properly

The Student Assessment, presented to the class in the Overview section of the Course, is designed to determine the entry level of the class in relation to treatment plant operations. It is very important that the instructors and Course Director have an appreciation of the level of knowledge of the students. It may even be possible, in some cases, to ask students to take the Student Assessment quiz prior to taking the course, and use it as a means of screening out those who are not well enough prepared, EPA may be providing courses in treatment plant operations that can be used as a prerequisite to this course on Troubleshooting.

The ideal class size is from 24 to 32 students, with multiples of 4 being preferable. Student selection, for any one session, should be made with these numbers in mind. Greater than 32 students can create difficulties for students and instructors alike in the presentation of course materials.

VI. *Instructors*

The three most important criteria in the selection of faculty for this course are a) knowledge of the treatment process being taught, b) practical experience with a facility using that treatment plant process and c) experience (and ability) to instruct adults using less traditional materials and techniques. In addition the Course Director should select instructors whom he believes have a positive attitude toward (and preferably experience in) the process of troubleshooting and technical assistance in the improvement of water quality.

Before any instructor is permitted to go before a class, the Course Director should schedule a briefing and preparation session in which a brief review of the overall course, and more specifically the lesson objectives, take place. Through discussion, there should be an assurance that the instructor is well-prepared and comfortable with the material and techniques which he will be using.

The Course Director should stress the difference in the role that the instructor may play during the presentation of his or her particular materials. For example, he or she may be the content resource person at the initial part of the lesson, and shift to the role of an educational manager during a group problem solving session.

It is particularly helpful if instructors are able to sit in on earlier sessions of the course, particularly the sessions on Overview, and Elements of Troubleshooting, so that they get a "feel" for the way the students are oriented toward the material. Having the instructors play the board game during the Overview session is an excellent orientation for them.

Preparation must be stressed to all prospective instructors. Even though course materials are thoroughly prepared, even "expert" instructors need some practice in presenting some of the techniques built into the lesson plans.

VII. *Physical Settling and Group Activities*

This course is designed with a variety of group activities and group work as a part of the instructional process. This means that the Course Director, in considering the physical setting for the course, needs to anticipate facilities which will accommodate the class in groups of four at tables and chairs, as well as auxiliary facilities for "break out" sessions. For example, since the course is designed to use groups of four, a class of 28 or 32 (multiples of four) would be a maximum number to accommodate in most education and training facilities of approximately 40 ft by 40 ft square. This would allow room for an 8 ft x 10 ft or 10 ft x 10 ft screen in the front of the room, a table-top lectern with a light, an easel, a pointer, a bar stool, and other paraphernalia and equipment to be located in the front of the room.

Set in a "herring-bone" design or *U* shaped configuration, so that most of each group of 4 are facing forward when necessary (but can move around to face each other at their particular groups and tables in group work), the room should also be equipped with a 35 mm, carousel-type automatic projector with a remote control switch extending to the table-top lectern, and a few extra chairs spaced at random around the back, side and speaker's area of the room.

In addition to the main meeting room, the Course Director should give preference to a separate room, set with card tables and chairs for use in the Board Game and three additional break out rooms (or a total of five rooms including the main classroom) so that the break out rooms can be set for the "fish bowl" role playing exercises called for in the Solids Handling Lesson (see Volume 10).

As soon as a complete registration list of students is available (usually not until the first day of the course), the Course Director should set up 4-person student groups. Groups should be wellbalanced, among persons (if possible) who are new to each other. For example, if enrollment in the course is half engineers, half biologists, some of each should be in each group. If the students are comprised of persons from several regional offices of a state agency, attendees from each office should be dispersed among several groups, so that each student can come in contact with "new" people from whom he can learn.

Student groups are first used in the Board Game portion of the Overview lesson. For the remainder of the course, groups should be seated together, inasmuch as they must frequently participate in group learning activities.

VIII. *Use and Preparation of Materials*

Attached to the 12 volumes of this course is a thirteenth volume which is identified as the Student Notebook. This contains all the materials the students will need for the entire course subdivided into thirteen sections from Overview to Chlorination. The materials in this Notebook will need to be reproduced in multiples to equal that of the number of students the Course Director anticipates attending the course. Naturally, if certain volumes and/or lessons of the course are not being included (for example, if Chlorination is not to be taught) then everything but the Chlorination student section would be reproduced for the course. Likewise, if a particular lesson is being taught in and by itself (for example, Troubleshooting and Oxidation Lagoons), then the Student Notebook materials for the Overview, the Elements of Troubleshooting, and Oxidation Lagoons would be reproduced for total number of students anticipated.

Since many of the lessons make reference to sections in USEPA's manual entitled "Procedural Manual for Evaluating the Performance of Wastewater Treatment Plants," copies of this manual should be made available to each member and instructor participating in the course. At the Course Director's direction, these copies can be retained at the conclusion of the course for use in another course. Care should be taken to obtain these from USEPA or the Government Printing Office, or reproduce them en masse as needed.

Additional materials need to be acquired for the Activated Sludge Lesson. For Subdivision 3, Copies of Part I and II of the pamphlets "Operator's Pocket Guide to Activated Sludge" should be distributed to each student. For Subdivision 8, materials on extended aeration which have been extracted from the WPCF Course MTM-01, are provided. The instructor may wish to consult the complete WPCF training package. Additional details are provided in the Activated Sludge lesson plan, Volume 9.

The following lessons have specific materials which will need to be duplicated for handing out at appropriate times during the course:

LESSON	**PAGES**	**PURPOSE**
Overview Vol. I	OV 2-(3 thru 12)	Student Assessment quiz and answer sheet
Elements of Troubleshooting Vol. I	ET 1-(9 thru 12)	Troubleshooting Dialogue Scripts (4 copies each needed)
Oxidation Lagoons Vol. IV	OL 2-(4 thru 6)	Problem/Answer Sheets for Group Troubleshooting Exercise
Activated Sludge Vol. IX	AS 5-(10 & 11)	Part II — Hamsborough Troubleshooting Problem
Solids Handling Vol. X	SH 2-(9 thru 14)	Instructions for Troubleshooting Problems
Closing Vol. I	CL 1-(3 thru 8)	Final Student Assessment Quiz
Closing Vol. I		Certificates awarded to students completing course

IX. *Lesson Plan Use and Mechanics*

Each Lesson Plan module and volume should serve as a self-contained set of:

A. Instructions to the instructor

B. Lesson outline

C. Visual aids

D. Notebook materials

E. Handout and other material

F. Guidelines on the approach to the lesson

Each lesson contains a section on Presentation Options to the Course Director. These should be reviewed while the course is in the planning stage, particularly because some of the options could affect the scheduling of the Course. There should be agreement between the Course Director and the instructor for any given lesson before major changes are made.

Each lesson plan outline is carefully timed. Instructors should be cautioned to observe the time schedules, and to become familiar with the "pace" of the lesson he is to give.

Instructors must become familiar with the visual aid and Notebook materials before attempting to present a lesson outline.

There is no reason why instructors cannot vary from the format or content of any given lesson, as long as the *lesson objectives* are maintained. However, all variations should be in the direction of *greater student participation.*

X. *Other Logistics*

Since the Course Director will need to consider a variety of logistics, depending upon the format, location, and participants of the course, the attached checklist will serve as a suggested checklist of special items to consider.

Again, the course developers have provided you with this detailed memorandum of instruction so that you would be aware of our thinking and planning throughout the development of the course. We hope that this information will be helpful to you in your plans for conducting what we consider to be a unique and exciting educational venture.

Good luck and best wishes.

TROUBLESHOOTING O&M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

CHECKLIST
of Activities
For Presenting the Course

A. Pre-Course Responsibilities:

____ 1. Reserve and confirm classroom(s), including size, "set-up," location and costs (if any).

____ 2. Contact and confirm all faculty (speakers) for the course(s), including their A-V requirements. Send material to them.

____ 3. Reserve hotel accommodations for faculty.

____ 4. Arrange for and confirm food service needs (i.e., meals, coffee breaks, water, etc)

____ 5. Review and modify program curricula in recognition of regional differences, based on your assessment of needs.

____ 6. Prepare and reproduce final ("revised" if appropriate) copy of the detailed program schedule.

____ 7. Reproduce final registration/attendance roster, including observers (if any).

____ 8. Prepare and send letter(s) of confirmation and instruction to all student participants (include biographical and educational questionnaire/information sheet to be returned by each participant — if used).

____ 9. Prepare and sign "Certificates of Completion." (if used)

____ 10. Prepare name badges and name "tents" for students and faculty.

____ 11. Identify, order, and confirm all A-V equipment needs.

____ 12. Prepare two or three 12 in. x 15 in. signs on posterboard for posting at meeting area.

____ 13. Arrange for and confirm any special administrative assistance needs on-site for course, including "local" Address of Welcome, etc.

____ 14. Obtain copies of EPA Manuals, and Activated Sludge Pamphlets.

____ 15. Pack and ship box of supplies and materials one week prior to beginning of course (if appropriate).

Checklist of Activities (Continued)

B. On-Site Course Responsibilities

____ 1. Check on and determine final room arrangements (i.e., tables, chairs, lectern, water, cups, etc).

____ 2. Set up A-V equipment required each day and brief operator (if supplied).

3. Post signs where needed.

____ 4. Alert receptionist, phone operator(s), watchmen, etc of name, location, and schedule of the program.

____ 5. Set up and handle final registration check-in procedures (including instruction to auxiliary help at registration desk).

____ 6. Conduct a new speaker(s) (i.e., instructor) briefing session on a daily basis.

____ 7. Verify and make final food services/coffee arrangements (where appropriate).

____ 8. Identify and arrange for other physical needs as required (i.e., coat racks, ashtrays, etc).

____ 9. Make a final check on arrival of guest speakers (instructors) for the day.

____10. Award certificates on last day of course.

C. Post-Course Responsibilities.

____ 1. Request honorarium and expense statements from faculty; order and process checks.

____ 2. Write thank-you letters and send checks to paid faculty.

____ 3. Write thank-you letters to non-paid guest speakers.

____ 4. Prepare evaluation on each course (including instructions, content, facilities, etc).

____ 5. Make sure A-V equipment is returned.

____ 6. Return unused materials to your office.

LESSON – COURSE OVERVIEW

Instructor Overview of Lesson

Entry Level Behavior: Students will have had University training in Sanitary Engineering, waste treatment and/or related sciences or equivalent in experience and training. Some field experience in inspecting treatment plants, but none in operating waste treatment facilities.

As a prerequisite to this course, it is recommended that the student will be able to

1. Identify treatment plant process units.
2. Describe treatment plant process units and equipment in technical terms.
3. Identify and explain the purpose of components of treatment plant process units, how they work and why they are important to the overall process.
4. Describe the normal operating procedures for treatment plant process unit components.
5. Identify when treatment plant process units are not operating properly.

Instructor Objectives: The principal instructor objectives for this lesson are:

1. To introduce the students to the course, its materials, the schedule, and particularly to each other.
2. To measure the overall level of the students in knowledge of treatment plant operations, to determine how well-prepared the students are for this course.
3. To relate treatment plant O&M to the overall perspective of the national water pollution control program.
4. To provide an overview of the course and to the Process of Troubleshooting as applied to treatment plant problems.

References: Note list of references included with student notebook materials.

Total Length of Lesson: 3 hours for 4 lesson subdivisions

LESSON OVERVIEW

Subdivision Title & Time	Major Student Objectives	Key Points & Content	Approach	Materials
1. Welcome, Introduction and Orientation 30 Minutes	1. To become familiar with purpose and nature of course 2. To be ready to proceed with the course	1. Introduction of students and faculty 2. Course Objectives 3. Course schedule and materials	1. Follow lesson outline 2. Be informed 3. Make students feel comfortable	1. Student notebook 2. EPA Manual – "Evaluating the Performance of Wastewater Treatment Plants"
2. Student Assessment 30 Minutes	1. To demonstrate knowledge of treatment plant operations	1. Exam on various facets of treatment plant operations	1. Instructor supervises exam 2. Instructor present to answer questions	1. Student assessment exam 2. Answer sheet 3. Answer key
3. The Significance of Plant O&M 30 Minutes	1. To know how troubleshooting O&M problems fits into the national water pollution control program 2. To identify factors found in a recent national survey which affect the performance of treatment plants	1. Importance of a balanced agency approach to controlling municipal discharges 2. Magnitude & scope of O&M problem 3. Results of Survey of Federally Funded Treatment Facilities	1. Follow lesson plan outline, using slides and key 2. Student discussion at appropriate points 3. Reference to student notebook	1. Slide series and slide key 2. Student notebook
4. Evaluating Treatment Plant Operations Board Game 90 Minutes	1. To be adequately prepared to participate in the remainder of the course.	1. Broad overview of course. 2. Working relationship between members of student groups. 3. Treatment Plant Problem Solving. 4. Troubleshooting as a process to solve complex problems.	Instructor supervises four stages to game. 1. Preparation 2. Instructions and initiation of play 3. Play 4. Conclusion of play	Complete sets of game materials are provided for each student group.

LESSON – COURSE OVERVIEW
Presentation Options for Course Director

The 180 minute lesson, *COURSE OVERVIEW*, is an essential introduction to this course. The developers of the course believe that this lesson must be used if the course is to be successful in its objectives. Accordingly, the options for varying from the lesson plan for this lesson are limited. Some possible alternative methods of presentation are suggested below should they be considered appropriate by the Course Director.

Subdivision 1 – Welcome, Introduction, and Orientation: Little variation in this subdivision is possible. Because one of the objectives is to establish a comfortable and informal environment, it may be possible to present this subdivision outside of the classroom, such as in a lounge. In one location, where the course began after lunch on the first day, this subdivision was presented in the dining room where all of the students and faculty were lunching together.

Subdivision 2 – Student Assessment: Little variation is possible. The student assessment is necessary to guide the Course Director and instructors.

Subdivision 3 – The Significance of Plant O&M: This subdivision offers considerable possibility for variation. Agencies presenting this course may substitute discussions of their own policies and programs for the prepared materials, as long as the overall subdivision objectives are met. It would also be possible to expand this subdivision beyond 30 minutes to provide additional discussion on agency policies. However, experience with this material shows that many course participants get very impatient with this type of lesson.

Subdivision 4 – Evaluating Treatment Plant Operations – Board Game: Little variation is possible in the presentation of the board game. However, because each of the student groups play the game using only one-half of all the problems, it would be possible to repeat the game later in the course with each group given the remaining set of problems. However, the developers of the course believe that there would be little educational purpose served by a repetition of the game.

COURSE OVERVIEW

Lesson Plan – Subdivision 1 **Time: 30 Minutes**

Title: WELCOME, INTRODUCTION AND ORIENTATION

Instructor Objectives: The instructor has the following objectives for this sequence of the course:

1. To make the students feel at home and comfortable.
2. To see that all of the students are introduced and identified. To insure that the students know who their fellow students are.
3. To introduce and identify the course faculty and staff.
4. To introduce the students to the course materials, and to identify the role of the materials in the course presentation.
5. To acknowledge the efforts of the developers of the course and to identify them to the students.
6. To present and discuss the objectives of the course.
7. To review the course format.
8. To review the schedule of presentation.
9. To answer all questions which students may have about the purpose or nature of the course.

Student Objectives: As a result of this lesson subdivision, students will be familiar with the purpose and nature of the course, and will be comfortable with the classroom setting and conditions. Following this subdivision, all students should be ready, and able to proceed with the content of the course, and with the student assessment which follows.

Training Materials

Student notebook

EPA Manual "Evaluating the Performance of Wastewater Treatment Plants."

Classroom Set-up

A normal classroom set-up will be required. Students may sit anywhere they please. Student seating will be rearranged later in the Course Overview lesson.

Subdivision Schedule

Within the 30 minute time period, the following schedule should be observed in presenting the lesson plan outline.

Time	**Subject**
0- 5 Minutes	Welcome and Introduction
5-25 Minutes	Introduction to the Course
25-30 Minutes	Official Welcome

Subdivision Approach

The instructor should follow the lesson outline. The instructor should attempt to be quite informal, to make the students feel comfortable, and to set a tone for the remainder of the course.

LESSON OUTLINE

I. Welcome and Introduction of Students (5 minutes)

A. Give brief words of welcome (1 minute)

B. Introduction of students. (4 minutes)
Each student should stand up and introduce himself by giving –

1. His name
2. Where he works, and for whom
3. The nature of his work

II. Introduction to the Course (20 minutes)

A. Introduction of Faculty (2 minutes)
Introduce all faculty, staff, EPA people, and other persons associated with the course.

B. Course Materials (2 minutes)
Introduce the students to the primary materials used for the course.

1. Student notebook – complete with reference materials, references and worksheets to be used by students as they are taking the course.
   This notebook should be present during all course lessons.
2. EPA Manual "Evaluating the Performance of Wastewater Treatment Plants."
3. Other course Materials
   If other course materials are to be used, they should be introduced at this point.

C. Acknowledgements (1 minute)

D. Course Objectives (10 minutes)

1. Refer students to Statement of Objectives, Student Notebook page OV-2.
2. Read objectives out loud to class.
3. Ask for questions and comments.

KEY POINTS & INSTRUCTOR GUIDE

Key Point: This course is designed so that students learn from each other. Therefore *they* are important to this course and should be introduced first.

Guide: Instructor should show each of the primary course materials to the class as he discusses them.

Guide: This manual is a major reference on plant troubleshooting. It should be used with the course and distributed to students whenever it is available.

Refer students to page OV-1, Student Notebook. Acknowledgements.

Key Points: It is important that the students appreciate the objectives of this course from the outset.

It is important for them to understand their expected behavior and capability at the completion of the course.

LESSON OUTLINE

E. Course Format and Schedule (5 minutes)
Refer students to the Student Notebook, including the *schedule* and the *index of subjects* covered.

Discuss the following points.

1. The course is structured into separate topics reflecting different treatment plant operations. This structuring is done primarily to facilitate the presentation of course materials and the assignment of instructors. However, treatment plants are considered as *waste treatment systems*, and troubleshooting should utilize a "system approach."
2. The course stresses a *problem solving* approach.
3. The course emphasizes *student participation* and involvement. The students will learn from each other as well as from the instructors.
4. The course utilizes a variety of instructional techniques to keep their interest, and because it's been shown that different people seem to respond best to different types of approaches.
5. Briefly discuss who the instructors will be, and their backgrounds.
6. Call attention to the course schedule, and the specifics of the schedule as appropriate to the particular presentation including:
   a. Course hours, and days, including starting times
      coffee breaks
      lunch breaks
      closing times
   b. Any evening sessions or other schedule deviations.
   c. Any take-home efforts or out-of-class efforts required by the students.

KEY POINTS & INSTRUCTOR GUIDE

Guide: Call the students' attention to the details of the course, and how it will be presented.

Key Point: Importance of viewing treatment plants as a system using a systematic approach to troubleshooting.

Key Point: Experienced students have much to contribute to this course.

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

III. Official Welcome (5 minutes)

If possible, students should be given a brief welcome from an official of the organization presenting the course, noting:

A. Its importance to water-quality programs, and to improving plant operations.

B. The importance of troubleshooting, and technical assistance.

C. The importance of cooperation between Federal, State, and Local governments, and where applicable, the private sector.

ACKNOWLEDGEMENTS

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AMERICAN PUBLIC WORKS ASSOCIATION:

Richard H. Sullivan, General Manager, Research Foundation

Malcolm C. VanDeursen, Director of Education
1313 East 60th Street
Chicago, Illinois 60637

Dr. Ira L. Whitman, P.E., Project Director
Environmental Engineering and Management
5300 E. Main Street, Columbus, Ohio 43213

PARTICIPATING CONSULTANTS:

Andrew P. Pajak, Green Engineers International, Sewickley, Pa.
Bobby D. Whitefield, Dudley E. Farr, Herbert T. Neuman, Texas Water Quality Board, Austin, Texas
Terry M. Regan, T.M Regan, Inc., Lexington, Kentucky
Dr. Earl A. Myers, Williams & Works Engineers, Grand Rapids, Michigan
Robert Manson, Charles Hull, Cliff Merritt, Ray Sancholtz, Greg Binder, Ohio EPA, Bowling Green, Ohio
Dr. Robert C. Polta, Richard W. DeFore, Metropolitan Waste Control Commission, St. Paul, Minnesota
David L. Sullivan, Engineering-Science, Inc., Berkely, Calif.
Dr. Ronald F. Layton, Water and Wastewater Technical School, Neosho, Missouri
James C. Haube, Water Pollution Control Department, Perrysburg, Ohio
Charles S. Zickefoose and R. B. Hayes, Stevens, Thompson & Runyan, Inc., Portland, Oregon
Dr. Donald Goldenbaum, Kansas City, Missouri

EPA TECHNICAL REVIEW COMMITTEE:

Dr. James O. Bryant, Jr., Municipal Operations Branch, EPA, Washington, D.C.
John W. Meagher, Municipal Operations Branch, EPA, Washington, D.C.
F. J. Ludzack, National Training Center, EPA, Cincinnati, Ohio
Joseph Joslin, EPA Region VII, Kansas City, Missouri
Art Gurley, EPA Region IV, Atlanta, Georgia
J. Edward Meers, Sanitary District of Bloom Township, Chicago Heights, Illinois

TROUBLESHOOTING OPERATING AND MAINTENANCE PROBLEMS AT WASTEWATER TREATMENT FACILITIES

COURSE OBJECTIVES:

- To train state and federal water pollution control personnel in the *process of troubleshooting* and problem solving for operational problems at municipal wastewater treatment plants. (And other persons in the water pollution control profession for whom the process of troubleshooting would be useful.)
- To upgrade the level of *technical assistance* provided to wastewater treatment plant operators by state and federal water pollution control agencies and personnel.
- To create an awareness for the need for *cooperative relationships and attitudes* between local, state, and federal agency staffs responsible for treatment plant performance and operations.
- To expose state and federal pollution control personnel to realistic *treatment plant operating problems*, their causes, effects, and methods of correction.
- To provide an overview of wastewater treatment plant operations and processes to serve as a *technical review* and supplement for water pollution control agency staffs.

AT THE COMPLETION OF THIS COURSE, STUDENTS WILL BE ABLE TO:

a. Assist treatment plant operators in a troubleshooting capacity by utilizing a constructive approach and positive attitude.

b. Identify operational problems in wastewater treatment plants, and their likely causes.

c. Utilize the process of troubleshooting to evaluate plant performance, and to conduct the necessary observations, tests, and process controls in the analysis of plant operating problems.

d. Identify and recommend alternative corrective actions to plant operating problems.

e. Recommend measures for the long range implementation of plant improvements and to monitor, document, and follow-up on the results of actions taken.

Lesson Plan – Subdivision 2 **Time: 30 Minutes**

Title: STUDENT ASSESSMENT

Instructor Objectives: The instructor is to present to the class a multiple choice test with 62 problems. The objective of the assessment is to determine the class's familiarity and knowledge of treatment plant operations. The test is to be graded and used by the course director to

1. Determine the overall level of this class in knowledge of treatment plant operations. Typical groups who have taken this course have had a median score of 75, with a typical range of 45 to 105. The maximum possible point total is 131.
2. Determine how many of the students seem to be deficient in their knowledge of plant operations. Knowledge of plant operations is a *must* for students to derive significant benefits from this course.
3. Determine if the class is particularly weak in certain subject areas. If so, the class can be given supplemental materials in those subjects. Alternatively, if time permits, additional classroom time could be spent in providing the fundamentals of whatever subjects the assessment shows that the class is particularly weak in.

As a result of this subdivision, the course director and instructors should have a clear picture of the level of knowledge of the class in treatment plant operations. This information should be used for the remainder of the course to guide and assist the instructors in determining which materials should be presented to the class in the various subject topics.

Training Materials

A copy of the student assessment exam is provided with the course materials. Copies should be made in advance of the course presentation for each member of the class, and distributed at the start of the student assessment period, along with accompanying answer sheets.

An answer key to the student assessment is provided with the course materials.

Classroom Set-up

A normal classroom set-up will be required. Students should be seated at tables or desks, with enough room to work on the assessment comfortably, and without interference from other students.

Subdivision Approach

The instructor should announce the purpose of the assessment and distribute the exam to each student. Students should be instructed to try to complete the test during the half-hour period. If they complete the test they should go back and review their answers. Students should be advised that many of the questions have *several* right answers.

The instructor should be present in the classroom during the exam to answer questions.

At the half-way point, the instructor should announce that the period is half over, and that those students who are not making sufficient progress should attempt to speed up their efforts.

At the end of the period, exam and answer papers should be collected.

The course director or an assistant should grade the exam papers. Using the "Answer Key" the grader should mark *only* the *correct* answers given by the student(s). Since it is the intention of this "test" to use the amount of knowledge the student(s) have about the various areas of treatment plant operations, the grader need not be concerned with "wrong" answers. However, if it is evident any student has consistently checked *all* the answers, he should be asked to re-take the test and instructed to check only those he believes to be correct. (It should be noted that in all the Demonstration Courses given by the Course Developers, there was no evidence of "wholesale" guessing on the "test.") Further, since the student(s) are not aware of the scoring process (correct answers only), this situation is highly unlikely.

The course director should determine the median score, and the range of scores. These should be announced later at a convenient break in the course. The course director should explain to the class the significance of the scores, noting that the letter codes on the answer sheet refer to the particular treatment process or lesson, such as AS=Activated Sludge, LP=Laboratory Practices, SH=Solids Handling, and so forth. As a fraction for each question, such as 1/3 for question No. 1, meaning the student knew one of the three possible correct answers on that particular Activated Sludge question.

Students who seek the information may be given their scores by the course director *in private*. Scores are not to be given out publicly in front of the entire class. The course developer attempted to "balance" the first column with the second column (or 1 through 31 with 32 through 62) with respect to treatment areas or lessons covered, as well as the total number of correct responses. Therefore, it is suggested that the course director encourage the student(s) with low total scores to give more significance to the score of the "first" column, since most students will have completed the first part more accurately (probably being "rushed" on the last half).

STUDENT ASSESSMENT

TROUBLESHOOTING OPERATING AND MAINTENANCE PROBLEMS AT MUNICIPAL WASTEWATER TREATMENT FACILITIES

1. The activated sludge process:
    ____a. Requires aeration
    ____b. Requires activated carbon
    ____c. Is a biological process
    ____d. Usually follows primary sedimentation
    ____e. Is an anaerobic process

2. If at all possible, samples for the BOD test should be collected before chlorination.
    ____a. True
    ____b. False

3. Sludge should be pumped from the primary clarifier to the digester several times a day to:
    ____a. Keep the pump from becoming clogged
    ____b. Prevent temporary overloading of the digester
    ____c. Maintain better conditions in the clarifier
    ____d. Permit thicker sludge pumping
    ____e. Prevent coning

4. If wastewater loading rates are too high, then
    ____a. Aerobic
    ____b. Anaerobic
    conditions may develop in the secondary clarifier.

5. Good supervision at wastewater treatment plants
    ____a. Is often reflected by good employee attitudes
    ____b. Is not all that important if operators and mechanics have good technical training.
    ____c. Probably won't affect the removal efficiency, but will create a cleaner, neater facility that everyone can be proud of
    ____d. Is something that comes naturally to skilled operators

6. In solving an operational problem at a treatment plant:
    ____a. There is always a "right" technical solution, it just takes time and experience to learn what it is
    ____b. Human errors may have to be corrected as well as mechanical errors
    ____c. Don't let the plant operator try to influence your judgment as to what the best solution is
    ____d. Standard textbooks in Sanitary Engineering are a major source of information

7. When the return sludge rate is too low, what happens?
    ____a. The tank will not fill
    ____b. There will be insufficient organisms to meet the waste load entering the aerator
    ____c. The activated sludge in the aerator will starve
    ____d. The activated sludge in the secondary clarifier could become septic
    ____e. The sludge blanket in the secondary clarifier could become too high

8. What factors influence the settling characteristics of solids in a clarifier?
___a. Flow velocity and/or turbulence
___b. Temperature
___c. Laboratory analyses
___d. Short circuiting
___e. Detention time

9. Lagoon scum rafts may be broken up by:
___a. Agitation with garden rakes
___b. Jets of water from pumps
___c. The use of outboard motors on boats
___d. Breaking down the bindings

10. High volatile acid/alkalinity relationship in a digester may be caused by:
___a. Overloading the tank with organic material
___b. Pumping too thin a raw sludge
___c. Filling the tank too full
___d. Withdrawing supernatant
___e. Adding lime

11. An operator should never be allowed to enter a room containing high concentrations of chlorine gas without:
___a. Help standing by
___b. Notifying proper authorities
___c. Using a self-contained air or oxygen supply

12. If you were advised by your supervisor that the treatment plant at community X was not operating to maximum design efficiency, and he asked you to "troubleshoot" to see if better results could be obtained, the first thing you might do would be:
___a. Review the monitoring reports submitted by the plant so you could learn more about their problems
___b. Call up the enforcement branch
___c. Call up the plant operator to schedule a visit to the plant
___d. Write a letter to the city director of public works ordering the city to meet a higher treatment removal efficiency

13. Primary clarifiers are designed to remove colloidal solids:
___a. True
___b. False

14. The main operational *process controls* for active sludge available to an operator include:
___a. Air rates
___b. Pounds of solids under aeration
___c. Maintenance
___d. Return sludge rates
___e. BOD test

15. The pilot flame in the waste gas burner should be checked daily to:

____a. Make sure it has not been blown out by the wind
____b. Prevent valuable gas from escaping
____c. Prevent odorous gas from escaping
____d. Prevent explosive conditions from developing
____e. Make sure proper temperatures are maintained in the digester

16. Large errors in laboratory tests may be caused by:

____a. Improper sampling
____b. Large samples
____c. Poor preservation
____d. Poor quality effluent
____e. Lack of mixing during compositing

17. In operating a trickling filter the operator should be trained to

____a. Adjust the process to obtain the best possible results for the least cost
____b. Use the lowest recirculation rates that will yield good results to conserve power
____c. Rotate the distributor as fast as possible to better spray settled wastewater over the media
____d. Maintain aerobic conditions in the filter
____e. Bubble oxygen up through the filter

18. How long would you allow activated sludge process to react and stabilize between operational changes?

____a. 3 hours
____b. 12 hours
____c. 1 day
____d. 2 days
____e. 1 week

19. The temperature of a digester should not be changed more than one degree per day to:

____a. Avoid excessive heat losses
____b. Avoid overloading the heat exchanger
____c. Allow the walls of the digester time to expand and contract
____d. Allow the organisms in the digester time to adjust to temperature changes
____e. Allow time for heating gas to be produced in the digester

20. Acceptance of the troubleshooter by the plant operators and supervisors is:

____a. Unimportant
____b. A plant problem
____c. Impossible
____d. Aided by troubleshooting
____e. Essential

21. Sprinkler clogging on a spray irrigation system can be cured by:

____a. Running a mild acid solution through the distribution system
____b. "blowing out" the solids by suddenly raising the pressure
____c. Adding more pumps to the system
____d. Periodic draining and flushing of the system

22. When operating an activated sludge plant, which is the most important suspended solids test for operational control?

____ a. Primary effluent
____ b. Aerator mixed liquor
____ c. Return sludge
____ d. Final clarifier effluent
____ e. Plant influent

23. To correct an odor problem in a trickling filter the operator should:

____ a. Take corrective action immediately
____ b. Shut off flow to the filter
____ c. Try to maintain aerobic conditions
____ d. Check ventilation in the filter
____ e. Increase recirculation rate

24. Package plants usually:

____ a. Operate the aeration device continuously
____ b. Have an operator at the plant 24 hours a day
____ c. Waste sludge out the effluent, but shouldn't when operated properly
____ d. Have an extensive lab testing program
____ e. Are affected by none of these

25. Which of the following are not responsibilities normally required of treatment plant operators?

____ a. Public relations
____ b. Plant design and modification
____ c. Supervision of plant personnel
____ d. Plant safety

26. A scum blanket in a digester may be broken up by:

____ a. Vigorously mixing the digester contents
____ b. Burning
____ c. Use of long poles
____ d. An ax

27. Lagoon performance can be indicated by what tests?

____ a. pH
____ b. Carbon dioxide
____ c. Methane
____ d. Dissolved oxygen
____ e. Hardness

28. If a flow meter does not read properly, what items should be checked as potential causes of error?

____ a. Installation of sensor and readout devices
____ b. Restrictions in the sensor and transmitter
____ c. Power supply to instruments
____ d. Check instruments according to manufacturer's instructions
____ e. Blow the transmission lines out with high pressure air

29. Operator training is:
    ___ a. A luxury that most public sewerage agencies cannot afford
    ___ b. Best done through correspondence courses
    ___ c. Necessary for operators to upgrade needed skills
    ___ d. Best done on the job

30. In spray irrigation and other land treatment methods, the system operator need not worry about
    ___ a. Final effluent color
    ___ b. Nutrient levels applied to crops
    ___ c. Weed killers
    ___ d. Odors

31. Chemicals commonly added for coagulation are:
    ___ a. Salts of potassium and sodium
    ___ b. Chlorine and iodine
    ___ c. Salts of iron and aluminum
    ___ d. Activated carbon

32. What could be happening if gas production in a digester starts decreasing?
    ___ a. The volatile acid/alkalinity relationship is increased
    ___ b. The raw sludge volume fed to the digester is decreasing
    ___ c. The raw sludge volume fed to the digester is excessive
    ___ d. The scum blanket is breaking up
    ___ e. The volatile acid/alkalinity relationship is decreasing

33. The pH scale may range from 0 to 14, with 6 being an acidic solution.
    ___ a. True
    ___ b. False

34. What items would you have checked if an activated sludge plant becomes upset?
    ___ a. Influent temperature
    ___ b. Daily flow rates
    ___ c. BOD loadings
    ___ d. Digester operation
    ___ e. Chlorinator

35. Lagoons may not operate properly if:
    ___ a. The influent organic matter content fluctuates considerably every few days
    ___ b. Temperature stays below freezing for a long time
    ___ c. There is no scum blanket
    ___ d. The influent contains a powerful fungicide in significant quantities
    ___ e. The influent has a high sulfur content

36. Causes of sludge bulking include:
    ___ a. Bulk of sludge too large
    ___ b. Air supply too low
    ___ c. Loading rate too high
    ___ d. Aeration period too short
    ___ e. Sludge going septic in secondary clarifier

37. Industrial waste materials which are not considered as compatible pollutants for municipal treatment plants include:
___a. Chemical oxygen demand
___b. Heavy metals
___c. Fats, oils, and greases
___d. Nitrogen and phosphorus compounds

38. It is important to listen carefully to various plant personnel in determining *how* to proceed in evaluating and solving problems:
___a. True
___b. False

39. Land Treatment
___a. Is never appropriate in a humid climate
___b. Should never be used in areas subject to below freezing temperatures
___c. Requires careful maintenance and operation
___d. Is not appropriate treatment process under new federal water pollution control laws

40. The effectiveness of the organisms in the aerator depends on the:
___a. Temperatueee
___b. pH
___c. Presence of inhibiting substances
___d. Characteristics of food supply
___e. Time of reaction or time available for the reaction

41. Which of the following statements regarding aerobic digesters are ture?
___a. They are simpler to operatre than anaerobic digesters
___b. Dissolved oxygen must be maintained above 4 milligrams per liter.
___c. They are most commonly found in very large treatment plants greater than 110 mgd
___d. The normal detention time is 15-25 days
___e. Sludge should be introduced once or twice a week

42. A good troubleshooter's attitude will convey:
___a. Efficiency
___b. Helpfulness
___c. Familiarity
___d. Confidence
___e. Friendliness

43. The answers from the total solids and suspended solids tests are always the same.
___a. True
___b. False

44. Which is probably not a good indicator of a defective collection system?
___a. Excessive grit in treatment plant influent
___b. High temperature sewage influent
___c. Septic odors
___d. Surcharges and by-passes of flows

45. Why should all of the diffusers in an aeration tank be cleaned at once?
- ___ a. To get the job done in a hurry
- ___ b. So the air will flow evenly out all of the diffusers
- ___ c. To improve step-feed aeration
- ___ d. So the plant won't use too much air
- ___ e. None of these

46. Aerobic digesters are more susceptible to upset than anaerobic digesters
- ___ a. True
- ___ b. False

47. If water is flowing off of a spray irrigation application area, the problem might be solved by:
- ___ a. Planting crops closer together
- ___ b. Adding fertilizers to the flow of effluent
- ___ c. Placing sprinklers further apart
- ___ d. Terracing or modifying contours of irrigated area

48. Chemical clarification is used to enhance the removal of:
- ___ a. Phosphorus
- ___ b. Heavy metals
- ___ c. Colloidal solids
- ___ d. Materials less dense than water

49. Results from the settleability test of activated sludge solids may be used to:
- ___ a. Calculate SVI
- ___ b. Calculate SDI
- ___ c. Calculate sludge age
- ___ d. Determine ability of solids to separate from liquid in final clarifier
- ___ e. Calculate mixed liquor suspended solids

50. Dissolved oxygen in a lagoon is increased by:
- ___ a. Surface aerators
- ___ b. Photosynthesis
- ___ c. Wind action
- ___ d. Algae liberating oxygen from the water molecule
- ___ e. Sludge gases from bottom deposits floating to the surface

51. Successful trickling filter operation depends upon:
- ___ a. Maintenance of a chlorine residual in the effluent
- ___ b. Washing slimes off the filter media
- ___ c. Preventing sludge bulking
- ___ d. Maintenance of a good growth of organisms on the filter media
- ___ e. Filtering the solids out of the wastewater

52. Sludge thickeners work on the principles of
- ___ a. Flotation
- ___ b. Filtration
- ___ c. Gravity settling
- ___ d. Centrifugal force
- ___ e. Anaerobic bacteria

53. The *two* principal elements of the troubleshooting process used by troubleshooters are problem identification and problem solving.
    ___ a. True
    ___ b. False

54. Final sedimentation is used in treatment plant following
    ___ a. Primary sedimentation
    ___ b. Trickling filters
    ___ c. Activated sludge
    ___ d. Chlorination

55. As a troubleshooter you should:
    ___ a. Be aware of the overall community's concern and goals affecting wastewater treatment
    ___ b. Not be concerned with outside-the-plant problems
    ___ c. Restrict your evaluation to in-plant operations
    ___ d. Use a check list to make a good impression
    ___ e. Send out news releases on your findings

56. Measuring flow in treatment plants:
    ___ a. Should only be done with V-notch weirs
    ___ b. Is a luxury most troubleshooters don't have to worry about
    ___ c. Is generally accurate and trouble free
    ___ d. Can be the key to troubleshooting several types of in-plant problems
    ___ e. Can be done with a variety of temporary expedients, if necessary

57. The main purpose of this course is to:
    ___ a. Make you a better wastewater treatment plant operator
    ___ b. Help you learn how to evaluate and assit in solving plant problems
    ___ c. Help you learn ways to have all plant personnel like you
    ___ d. Teach you how to write citations for plant operation violations

58. Problems associated with trickling filters include:
    ___ a. Bulking
    ___ b. Filter Flies
    ___ c. Clogging
    ___ d. Turbid effluent
    ___ e. Snails

59. Short circuiting in a final sedimentation process
    ___ a. Is probably caused by mechanical failures
    ___ b. Usually represents a hydraulic deficiency of design or operation
    ___ c. Increases efficiency by facilitating rapid movement of treatment plant effluent

60. A troubleshooter shouldn't offer suggestions unless he is asked for help
    ___ a. True
    ___ b. False

61. Which of the following solids handling processes is out of sequence with the other processes?

____a. Dewatering
____b. Thickening
____c. Stabilization and digestion
____d. Final disposal

62. Chlorinators should be located:

____a. Near point of application
____b. Outdoors
____c. In a separate room
____d. In a room that will not allow chlorine to leak into rooms where operators work or where controls and equipment are located
____e. In an adequately heated room

TROUBLESHOOTING OPERATING AND MAINTENANCE PROBLEMS AT MUNICIPAL WASTEWATER TREATMENT FACILITIES

STUDENT ASSESSMENT – ANSWER SHEET

Please circle your answer(s)	FOR OFFICE USE ONLY			FOR OFFICE USE ONLY	
1. a b c d e		AS	32. a b c d e		SH
2. True False		LP	33. True False		LP
3. a b c d e		SH	34. a b c d e		AS
4. a b		AS	35. a b c d e		OL
5. a b c d		MB	36. a b c d e		AS
6. a b c d		ET	37. a b c d		PR
7. a b c d e		AS	38. True False		ET
8. a b c d e		PR	39. a b c d		LT
9. a b c d		OL	40. a b c d e		AS
10. a b c d e		SH	41. a b c d e		SH
11. a b c		CH	42. a b c d e		ET
12. a b c d		ET	43. True False		LP
13. True False		PR	44. a b c d		PR
14. a b c d e		AS	45. a b c d e		AS
15. a b c d e		SH	46. True False		SH
16. a b c d e		LP	47. a b c d		LT
17. a b c d e		TF	48. a b c d		CA
18. a b c d e		AS	49. a b c d e		AS
19. a b c d e		SH	50. a b c d e		OL
20. a b c d e		OV	51. a b c d e		TF
21. a b c d		LT	52. a b c d e		SH
22. a b c d e		AS	53. True False		ET
23. a b c d e		TF	54. a b c d		AS
24. a b c d e		AS	55. a b c d e		MB
25. a b c d		MB	56. a b c d e		FM
26. a b c d		SH	57. a b c d		OV
27. a b c d e		OL	58. a b c d e		TF
28. a b c d e		FM	59. a b c		AS
29. a b c d		MB	60. True False		ET
30. a b c d		LT	61. a b c d		SH
31. a b c d		CA	62. a b c d e		CH

Date ____________________

Name ____________________

COURSE OVERVIEW

Lesson Plan – Subdivision 3 **Time: 30 Minutes**

Title: THE SIGNIFICANCE OF PLANT O&M

Instructor Objectives: To present troubleshooting treatment plant problems, and operation and maintenance, in the context of the overall national program of water pollution control. To review the distribution of treatment plants by type and by population, nationally and regionally. To present the results of the recent survey of Federally funded treatment facilities, and the operation and maintenance deficiencies found nationally among municipal waste treatment plants.

Student Objectives: As a result of this lesson subdivision, students will be able to do the following:

1. Discuss the basic elements of the National Water Pollution Control Program.
2. List the means available under federal law for the control of municipal discharges.
3. Discuss the role of troubleshooting for operation and maintenance problems in the overall effort for improving treatment plant effluent quality.
4. Identify the elements of inter-agency cooperation necessary to improve operations and maintenance at treatment plants through technical assistance.
5. Relate local circumstances with regard to treatment plant distribution to regional and national statistics.
6. List the results of the recent survey of Federally funded treatment facilities.
7. Identify those factors, found in the survey, which affect the performance of municipal wastewater treatment plants.
8. Fully comprehend the need for troubleshooting as part of a national effort to upgrade the performance of municipal wastewater treatment plants.

Training Materials:

Slide Series of eleven (11) slides, with Slide Key as part of lesson plan outline.

Student Notebook page OV-3, Summary of Survey of Federally Funded Treatment Facilities

Classroom Set-up:

A normal classroom set-up will be required.
35 mm carousel slide projector with remote controls
Large Screen (8 ft x 10 ft)
Chalkboard or Easel
Pointer

Subdivision Schedule:

Within the 30 minute time period the following schedule should be observed in presenting the lesson plan outline.

Time	Subject
0-10 Minutes	Perspective of Troubleshooting Plant Problems
10-25 Minutes	Survey of Treatment Facilities
25-30 Minutes	Local Applicability

Subdivision Approach:

The instructor is to rely upon the lesson outline, using the slide series and slide key. Student discussion and participation is called for at appropriate places within the lesson plan outline. Students are to refer to Student Notebook page OV-3 during the lesson plan section II-B.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
I. Persepective of Troubleshooting Plant Problems in Relation to the National Water Pollution Control Program (10 minutes)	Guide: The purpose of this section is to relate troubleshooting plant problems to the larger elements of water pollution control.
A. Troubleshooting plant problems is a small but *real* part of the nation's effort to control water pollution. Current programs are derived from the Federal Water Pollution Control Amendments of 1972 as follows:	
"National Programs to Control Water Pollution" • PL 92-500 (1972) calls for • Restoring and preserving quality of the nation's waters, by • Controlling point source discharges with • Higher levels of waste removal, and • A national permit system – NPDES	SLIDE OV-1 (word)
"To Make NPDES Work – We Need" • More effective plant operation • State and federal EPA inspections and plant evaluations • Technical assistance to plant operators, through TROUBLESHOOTING	SLIDE OV-2 (word)
"Municipal Discharge Control Requires Combination Of" • New plant construction – grant program • Plant upgrading and enlarging • Compliance monitoring and surveillance • Permit enforcement • O&M Upgrading • Technical Assistance – Troubleshooting	SLIDE OV-3 (word) Key Point: The most effective municipal discharge control program offers a balance between enforcement, technical assistance and new construction. All of these tools should be used by states and EPA when appropriate.
"Need for Troubleshooting Based On" • Cost and complexity of plants • Upgraded performance requirements for plants • Surveys showing deficiencies in plant operations • Experience of State and EPA field staffs	SLIDE OV-4 (word)

LESSON OUTLINE

"Troubleshooter Training – Course Objectives"

- Train Pollution Control Personnel in the Process of Troubleshooting
- Upgrade Technical Assistance
- Cooperative Attitudes and Relationships
- Realistic Plant Problems
- Technical Review of Plant Processes

B. Interagency Cooperation – Improving O&M through technical assistance requires cooperation at all levels.

1. Local government
   a. Operates majority of plants – must be receptive to state and federal technical assistance
   b. Must better train its personnel
   c. Must be willing to fund operational improvements
2. State Government
   a. Can provide field people for technical assistance
   b. Can help train and upgrade operators
   c. Can use a balanced approach between enforcement, technical assistance and grants
3. Federal Government
   a. Can provide manuals, new information, and help upgrade state-of-the-art
   b. EPA regions, and special facilities such as the National Waste Treatment Center in Cincinnati can provide significant technical assistance
   c. Upgrade the use and value of O&M Manuals
   d. Support training programs related to O&M
4. Private Consultants – Have an expanding role in O&M improvements
   a. *Should* design plants with O&M considerations accounted for
   b. Can produce good O&M manuals
   c. Can provide operational assistance to clients

KEY POINTS & INSTRUCTOR GUIDE

SLIDE OV-5 (word)
Review this slide which lists the objectives of this course.

Key Point: Stress the essential role of each level of government, and the need for cooperation.

Note:
If time permits, class discussion of this topic should be encouraged.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
II. Survey of Federally Funded Treatment Facilities (Done Under Section 210 of the Water Pollution Control Act) (15 Minutes)	
A. Distribution of Treatment Plants Nationally, and by EPA region	Key Point: This section is presented to illustrate the magnitude and scope of the national O&M problem. 6 slides are presented four on the national distribution of plants, and two on the regional distribution. The instructor must select the slides pertinent to the appropriate EPA Region.
1. National Distribution of Treatment Facilities	SLIDE OV-6 (chart) Significance: There is a wide distribution of types of plants. Largest number – Oxidation Ponds.
2. National Distribution – Treatment Classification by Population	SLIDE OV-7 (chart) Significance: Largest population served by primary-intermediate, and activated sludge plants.
3. National Distribution of Secondary Treatment Facilities	SLIDE OV-8 (chart)
4. National Secondary Treatment Classification by Population	SLIDE OV-9 (chart) Significance: By far, largest population served by activated sludge.
5. Regional Distribution of Treatment Facilities	SLIDE OV-10 (chart) Select Slide for appropriate EPA Region.
6. Regional Distribution – Treatment Classification by Population	SLIDE OV-11 (chart) Select Slide for appropriate EPA region. Guide: Point out possible differences in region where course is being presented from the national figures.

LESSON OUTLINE

B. Survey Results

1. Plant Performance
    a. Less than half of secondary facilities are meeting secondary effluent requirements
    b. Trickling filters have more difficulty meeting requirements than activated sludge
    c. 4,400 secondary plants may not be in compliance
2. Marginal Plants
    a. 20 percent of all secondary plants – up to 1,700 nationally, are classified as "marginal performers"
    b. Marginal performers – do not meet secondary requirements, but
    c. They can meet secondary requirements without significant investments in new construction, thus
    d. Some 1,700 plants could achieve requirements through O&M and minor plant modifications.
3. Laboratory Facilities
    a. Many plants had inadequate lab facilities, thus
    b. Many facilities could not provide adequate operational data
    c. Testing for process control is low due to inadequate lab facilities
    d. Illinois Survey – With an adequate lab plant performance can be increased by 20 percent
4. Other factors
    a. Plants with good maintenance management programs perform better
    b. Attention to routine training, short courses, etc., has been lacking.

KEY POINTS & INSTRUCTOR GUIDE

Guide: Review details of national survey to illustrate the nature of the national O&M problem.

Refer Students to Summary of Survey, Student Notebook, page OV-3.

LESSON OUTLINE

5. Survey Conclusions
   a. Improved O&M practices, laboratory facilities and training can lead to *major* levels of plant performance improvements, and will enable an additional 20 percent of all secondary plants to meet existing requirements
   b. Based on EPA experience direct operational assistance to plant operators by providing an effective control strategy can result in significant improvement in effluent quality.
   c. Assistance programs exemplified by work of A.W. West, National Waste Treatment Center, EPA Cincinnati – considerable success in providing control methodologies for activated sludge facilities

6. Significance
   a. As a result of EPA Survey and conclusions, troubleshooting O&M technical assistance must be stressed as an important part of the overall clean-up effort for water pollution

III. Local Applicability (5 minutes)

The remaining time for this subdivision should be used by the instructor to "localize" this lesson to the specific situation of the area where the course is presented.

A. Are the Survey results applicable?

B. Is the distribution of plants comparable to the regional and national distribution

C. Are there special problems locally not identified in the Survey?

KEY POINTS & INSTRUCTOR GUIDE

Note: Refer students to papers by Gilbert, listed in Notebook under references for this lesson.

Guide: Attempt to establish class discussion on the Survey results and conclusions.

Note: Student input should be sought for this discussion.

COURSE OVERVIEW

Lesson Plan – Subdivision 4 **Time: 30 Minutes**

Title: EVALUATING TREATMENT PLANT OPERATIONS – BOARD GAME

Instructor Objectives: The instructor's objectives for the board game are:

1. To provide a broad overview of the content area of the course.
2. To introduce students, on a working relationship, to other students not previously known to them.
3. To immerse the students quickly into the course by having them participate in solving treatment plant operating problems.
4. To introduce the students, through the game problems, to the complexity of some situations encountered in a troubleshooting capacity.
5. To force the students to think, through their participation, of troubleshooting as a process, and not merely as the recital of knowledge previously acquired.
6. To introduce the students to learning through group interactions.

Student Objectives: As a result of this lesson subdivision, and the other subdivisions in the Course Overview lesson, students will be adequately prepared to participate in the remainder of the course.

Training Materials: The board game comes self-contained with the following materials:

1. Game board
2. A pair of dice
3. One marker each for 4 players
4. Problem cards in two sets
    - One set of 10 odd numbered cards, Nos. 1,3,5,7,9,11,13,15,17,19
    - One set of 10 even numbered cards, Nos. 2,4,6,8,10,12,14,16,18,20
5. Sixty (60) solution cards
6. Instruction sheets
7. Scenario sheets
8. Score sheets

The course director or instructor should provide one pen for each game table, for keeping score.

Small prizes may be provided to winning and losing groups. Such prizes as cracker-jacks, lifesavers, cigars, etc., have proven to be popular.

Classroom Set-up: The classroom is to be set up using card tables (preferably), or other tables accommodating groups of four (4) players. It is desirable for all of the groups playing the game to be located in one room. Sufficient space should be left between tables to allow the groups to comfortably engage in normal conversation.

Subdivision Schedule: Within the 90 minute time period, the following schedule should be observed in presenting the board game.

Time	Activity
0 – 5 Minutes	Instructor introduces game, its purposes, and how to play.
5 – 15 Minutes	Students read instructions. Instructor reads scenario out loud.
15–20 Minutes	Solution cards are given out, students shuffle and deal.
20 Minutes	Play begins
60 Minutes	Students are reminded that they have 20 minutes remaining. They should speed up their play if they are not at least up to the seventh problem.
80 Minutes	Play is over.
80–90 Minutes	Student groups tally their scores, report to instructor. Instructor awards prizes. Class discusses game and their reaction to it.

Subdivision Approach: The instructor must supervise the playing of the game from beginning to end. There are four stages to presenting the game as follows:

Stage 1: Preparation
Stage 2: Instructions and initiation of play
Stage 3: Play
Stage 4: Conclusion of play

The details of the instructor's role in supervising the game are presented in the following lesson outline.

LESSON ACTIVITY	KEY POINTS & INSTRUCTOR GUIDE
I. Preparations for Game (15-30 minutes) The following preparations should be made by the instructor prior to having the class play the board game.	Guide: All game preparations must be completed **prior** to the start of the lesson subdivision.
A. Set up card tables in area where game is to be played.	
B. Set tables with game boards, and all game materials *except solution cards*, which are to be distributed later.	
C. Problem cards are to be placed, face down, in numerical order, with the pack of problem cards rubber-banded.	
D. Groups of four students each should be pre-selected from course roster by the course director. If possible, students should be grouped so that members of the same group do not know each other prior to the course. If the students in the course have varied backgrounds, groups should be mixed so that the players in each group represent the various backgrounds, i.e., MIX-IT-UP!	Note: The composition of the groups should be announced at the completion of subdivision 3. Groups should be kept intact for the lessons which follow this one.
II. Instructions and Initiation of Play (20 minutes)	
A. Introduce the Game (5 minutes)	
1. Review objectives of the game with the class	Guide: These three points are essential to the success of the game.
2. Make it clear to the class that students work in *groups*. Each group *competes* against all other groups. Individuals do not compete with one another.	
3. State that in playing the game, the objective of each group is to successfully troubleshoot treatment plant problems.	

LESSON ACTIVITY

B. Instructions (10 minutes)
  1. Have students read game instructions
  2. Review principal game instructions with class. Answer any questions with regard to how game is played.
  3. Scenario: Have students read Scenario along with instructor who reads Scenario out loud.
  4. Announce that all solutions are judged in the *context* of the Scenario

C. Initiation of Play (5 minutes)
  1. Distribute one pack of Solution Cards to each table.
  2. Players shuffle Solution Cards
  3. Each player is dealt 12 Solution Cards, which he places face upward (text showing) in front of him on the table, arranged so that he can read his cards easily. The remaining 12 Solution Cards are placed face downward in a pack in the appropriate square on the board.
  4. Students should look at and learn the contents of each of the 12 Solution Cards at their place
  5. Instructor should point out that there is always a chance that a group *will not* have the right solution to a problem face up, inasmuch as 1/5 of all solution cards are face down in the pack
  6. Players should roll dice and begin

III. **Play (60 minutes)**

A. At the start of play, instructor should provide guidance to see that each group understands the rules.

B. Instructor should make sure that groups *discuss* their problem solutions between them. This discussion is very important and should be encouraged.

KEY POINTS & INSTRUCTOR GUIDE

Key Point: In the "real world" the right solution is not always available – thus the element of chance.

Instructors should remain present to observe play and answer questions.

LESSON ACTIVITY

C. Questions and comments that come up during play
   1. Two "doubles" in a row. If a group lands on the "double" square two plays in a row, the next problem *does not count* four times the value. Instead, the next two problems *each* count twice the value
   2. What is a "stuck" digester. This expression is not universally known. It is a digester that is not operating, not generating gas. It does not mean that the cover is stuck.
   3. Groups occasionally complain that a "correct" answer is incorrest, or vice-versa. Instructor should comment that the course developers judged these answers correct in relation to the Scenario, and that some answers are arguable. However, *no* adjustment in the scores should be allowed.
   4. Groups occasionally feel cheated because none of the players had a correct solution card in front of them. Explain that this is due to the element of chance, and that all groups have the same odds. However, this parallels reality, in that most troubleshooters, with their own background and training, rarely have all of the answers available to them. Troubleshooting is a learning process as well.

D. After 40 minutes, encourage all groups to complete their 10 problems in the remaining 20 minutes.

IV. Conclusion of Play (10 minutes)

A. Call play to a halt

B. Have each group add up the number of checks (√)

C. Any group with 5 or more X's may not win.

D. Have each group announce its score.

E. Award prizes to groups with highest and lowest scores.
   A score of 15 √'s is considered good-par for the game.
   The highest score obtained after seven presentations was 24.

KEY POINTS & INSTRUCTOR GUIDE

In the time remaining, seek class reaction to the game and comments.

SCENARIO OF BOARD GAME

The Board of Trustees of Independence County, located in the urban-industrial center of your state, has recently voted to establish a consolidated, county-wide sanitary district which will construct, own, and operate all municipal sewerage facilities in the county. The District will assume jurisdiction over all existing treatment plants in the county, including those in the less populated, rural areas, and those serving private subdivisions. In all, when it comes into existence, the District will acquire the following facilities:

a. Three (3) activated sludge, (secondary treatment) plants, with industrial waste loads. Capacity: 2.5 to 60 mgd.
b. Five (5) trickling filtration, (secondary treatment) plants, some with industrial waste loads, capacity: .75 to 9.0 mgd.
c. Twelve (12) aerated lagoons, capacity: .10 to .70 mgd.
d. One (1) primary treatment plant, 5 mgd.
e. Two (2) spray irrigation facilities, handling a total load of .25 mgd, following secondary treatment.
f. One (1) advanced waste treatment plant, .2 mgd, which consists of chemical clarification, sand filtration, activated carbon adsorption, with nitrification.
g. A variety of sludge handling facilities, including anaerobic digestion, sludge drying beds, vacuum filtration, incineration and landfill.
h. Twenty-five (25) "package" treatment plants serving residential subdivisions.

Your boss, the Commissioner of Water Pollution Control for the State, has promised the new Executive Director of the Sanitary District, the State's full cooperation in assisting the District assume the operation of all of its facilities. The Executive Director, brought in from another State for the job, has heard rumors of faulty and inefficient operations at many of the facilities he is about to control, and has seen some evidence to this effect in the operating records of the District's plants. Because of his concerns, the Commissioner has promised to send a team of the State's top field people to troubleshoot at the plants in Independence County.

You are a specialist in treatment operations for the State, but have been working in the State Capitol and you are unfamiliar with the plants, the problems and the personnel in the new Independence County Sanitary District. You will head a team of three (3) other specialists and will be assigned to assist the District in improving treatment plant operations throughout the county. You will rely on the judgment of the members of your team, and of course, on the plant operators; but you have been given the final authority to determine what, if any, changes need to be made at the plants which you are about to evaluate. All plant superintendents and operators in the District have been notified that your evaluation team will visit their plants to assist them in upgrading performance. Your recommendations are to go directly to the new Executive Director.

REFERENCES – COURSE OVERVIEW

Gilbert, W.G. Municipal Wastewater Treatment: The Relation of Operation and Maintenance Activities to Plant Efficiency. Presented at 48th Annual Conference, Water Pollution Control Federation. Miami Beach, October, 1975.

Azan, K.M. and B.I. Boyko. Identification of Problem Areas in Water Pollution Control Plants. Research Report No. 15. Ontario Ministry of the Environment, 1973.

Public Law 92-500. Federal Water Pollution Control Act Amendments. Adopted October 18, 1972.

STUDENT NOTEBOOK MATERIALS

The following materials are included in the section of the Student Notebook on COURSE OVERVIEW. The Notebook is distributed to students at the start of the course, and is available to them as a reference throughout the course.

Index of Notebook Materials

Pages	Material	Use in Lesson
OV-1	Acknowledgements	For student reference, Subdivision 1, Section II
OV-2	Course Objectives	Used by students and instructor, Subdivision 1, Section II
OV-3	Summary of Survey of Federally Funded Treatment Facilities	For student reference, Subdivision 3, Section II
OV-4	Scenario of Board Game	For student reference from board game, Subdivision 4
OV-5	References	

ACKNOWLEDGEMENTS

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AMERICAN PUBLIC WORKS ASSOCIATION:

Richard H. Sullivan, General Manager, Research Foundation

Malcolm C. VanDeursen, Director of Education
1313 East 60th Street
Chicago, Illinois 60637

Dr. Ira L. Whitman, P.E., Project Director
Environmental Engineering and Management
5300 E. Main Street, Columbus, Ohio 43213

PARTICIPATING CONSULTANTS:

Andrew P. Pajak, Green Engineers International, Sewickley, Pa.
Bobby D. Whitefield, Dudley E. Farr, Herbert T. Neuman, Texas Water Quality Board, Austin, Texas
Terry M. Regan, T.M. Regan, Inc., Lexington, Kentucky
Dr. Earl A. Myers, Williams & Works Engineers, Grand Rapids, Michigan
Robert Manson, Charles Hull, Cliff Merritt, Ray Saneholtz, Greg Binder, Ohio EPA, Bowling Green, Ohio
Dr. Robert C. Polta, Richard W. DeFore, Metropolitan Waste Control Commission, St. Paul, Minnesota
David L. Sullivan, Engineering-Science, Inc., Berkely, Calif.
Dr. Ronald F. Layton, Water and Wastewater Technical School, Neosho, Missouri
James C. Haube, Water Pollution Control Department, Perrysburg, Ohio
Charles S. Zickefoose and R. B. Hayes, Stevens, Thompson & Runyan, Inc., Portland, Oregon
Dr. Donald Goldenbaum, Kansas City, Missouri

EPA TECHNICAL REVIEW COMMITTEE:

Dr. James O. Bryant, Jr., Municipal Operations Branch, EPA, Washington, D.C.
John W. Meagher, Municipal Operations Branch, EPA, Washington, D.C.
F. J. Ludzack, National Training Center, EPA, Cincinnati, Ohio
Joseph Joslin, EPA Region VII, Kansas City, Missouri
Art Gurley, EPA Region IV, Atlanta, Georgia
J. Edward Meers, Sanitary District of Bloom Township, Chicago Heights, Illinois

TROUBLESHOOTING OPERATING AND MAINTENANCE PROBLEMS AT WASTEWATER TREATMENT FACILITIES

COURSE OBJECTIVES:

- To train state and federal water pollution control personnel in the *process of troubleshooting* and problem solving for operational problems at municipal wastewater treatment plants. (And other persons in the water pollution control profession for whom the process of troubleshooting would be useful.)
- To upgrade the level of *technical assistance* provided to wastewater treatment plant operators by state and federal water pollution control agencies and personnel.
- To create an awareness for the need for *cooperative relationships and attitudes* between local, state, and federal agency staffs responsible for treatment plant performance and operations.
- To expose state and federal pollution control personnel to realistic *treatment plant operating problems*, their causes, effects, and methods of correction.
- To provide an overview of wastewater treatment plant operations and processes to serve as a *technical review* and supplement for water pollution control agency staffs.

AT THE COMPLETION OF THIS COURSE, STUDENTS WILL BE ABLE TO:

a. Assist treatment plant operators in a troubleshooting capacity by utilizing a constructive approach and positive attitude.

b. Identify operational problems in wastewater treatment plants, and their likely causes.

c. Utilize the process of troubleshooting to evaluate plant performance, and to conduct the necessary observations, tests, and process controls in the analysis of plant operating problems.

d. Identify and recommend alternative corrective actions to plant operating problems.

e. Recommend measures for the long range implementation of plant improvements and to monitor, document, and follow-up on the results of actions taken.

SUMMARY OF

Survey of Federally Funded Treatment Facilities
(Done under Section 210 of the Water Pollution Control Act)

1. **PLANT PERFORMANCE**
   - a. Less than half of secondary facilities are meeting secondary efflent requirements.
   - b. Trickling filters have more difficulty meeting requirements than activated sludge.
   - c. 4,400 secondary plants may not be in compliance.
2. **MARGINAL PLANTS**
   - a. 20% of all secondary plants – up to 1,700 nationally, are classified as "marginal performers"
   - b. Marginal performers – do not meet secondary requirements, but
   - c. They can meet secondary requirements without significant investments in new construction, thus
   - d. Some 1,700 plants could achieve requirements through O&M and minor plant modifications.
3. **LABORATORY FACILITIES**
   - a. Many plants had inadequate lab facilities, thus
   - b. Many facilities could not provide adequate operational data
   - c. Testing for process control is low due to inadequate lab facilities
   - d. Illinois Survey – With an adequate lab, plant performance can be increased by 20%.
4. **OTHER FACTORS**
   - a. Plants with good maintenance management programs perform better
   - b. Attention to routine training, short courses, etc., has been lacking
5. **SURVEY CONCLUSIONS**
   - a. Improved O&M practices, laboratory facilities, and training can lead to *major* levels of plant performance improvements, and will enable 20% of all secondary plants to meet existing requirements
   - b. Based on EPA experience, direct operational assistance to plant operators by providing an effective control strategy can result in significant improvements in effluent quality
   - c. Assistance programs exemplified by work of A. W. West, National Waste Treatment Center, EPA Cincinnati – considerable success in providing control methodologies for activated sludge facilities
6. **SIGNIFICANCE**
   - a. As a result of EPA Survey and conclusions, troubleshooting O&M problems, and O&M technical assistance must be stressed as an important part of the overall cleanup effort for water pollution

For more information see Gilbert, W.G. (listing in References)

SCENARIO OF BOARD GAME

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REFERENCES – COURSE OVERVIEW

Gilbert, W.G., "Municipal Wastewater Treatment: The Relation of Operation and Maintenance Activities to Plant Efficiency," Presented at 48th Annual Conference, Water Pollution Control Federation, Miami Beach, October, 1975.

Azan, K.M., and Boyko, B.I., "Identification of Problem Areas in Water Pollution Control Plants," Research Report No. 15, Ontario Ministry of the Environment, 1973.

Public Law 92-500, Federal Water Pollution Control Act Amendments, Adopted October 18, 1972.

LESSON – ELEMENTS OF TROUBLESHOOTING

Instructor Overview of Lesson

Entry Level Behavior: Students will have had University training in Sanitary Engineering, waste treatment and/or related sciences or equivalent in experience and training. Some field experience in inspecting treatment plants, but no experience in operating waste treatment facilities.

As a prerequisite to this course, it is recommended that the student will be able to –

1. Identify treatment plant process units.
2. Describe treatment plant process units and equipment in technical terms.
3. Identify and explain the purpose of components of treatment plant process units, how they work and why they are important to the overall process.
4. Describe the normal operating procedures for treatment plant process unit components.
5. Identify when treatment plant process units are not operating properly.

Instructor Objectives: The principal instructor objectives for this lesson are:

1. To present and illustrate the proper attitudes and elements of human behavior required for effective troubleshooting.
2. To present and discuss a systematic Process of Troubleshooting that can be used to approach operational problems at wastewater treatment plants.

Total Length of Lesson: 90 Minutes for two lesson subdivisions.

LESSON – ELEMENTS OF TROUBLESHOOTING

Presentation Options for Course Director

The 90 minute lesson on ELEMENTS OF TROUBLESHOOTING sets the stage for the entire course. Principles introduced in this lesson are expanded upon and reinforced in subsequent lessons. Therefore, this lesson is absolutely essential to the course. It cannot be eliminated, and should not be reduced in length of time, or in scope.

If this lesson were to be eliminated, some of the basic points of the course would be lost. Therefore, there are few options available for modification.

The only presentation option considered by the course developers to be potentially worthwhile would be the use of additional faculty in the lesson who have experienced troubleshooting and can reinforce the approach being presented. Such persons might be operators, plant superintendents, municipal or sewer district officials, or state or EPA field and O&M personnel. Such persons could be called on to illustrate the lesson by relating some of their own personal experiences in troubleshooting.

LESSON OVERVIEW

Subdivision Title & Time	Major Student Objectives	Key Points & Content	Approach	Materials
1. Attitudes and Human Behavior in Troubleshooting 45 Minutes	1. Define troubleshooting 2. Relate human behavior aspects of troubleshooting to their own jobs 3. Discuss the role of troubleshooters in relation to plant operators 4. Differentiate between human and technical skills. 5. Compare positive and negative types of troubleshooter behavior	1. Human attitudes and behavior in troubleshooting 2. Analysis of type of troubleshooter behavior 3. Good characteristics of troubleshooter behavior	1. Use outline and slides, maximize class discussion. 2. Present two troubleshooting dialogues 3. Analyze two troubleshooting dialogues with class discussion 4. Discuss troubleshooter behavior, using chalkboard to record input	1. Slide series and key 2. Troubleshooting dialogues No. 1 and No. 2, scripts 3. Student Notebook page ET-1
2. The Process of Troubleshooting 45 Minutes	1. List the basic elements of troubleshooting 2. Use the chart, the Process of Troubleshooting 3. Locate and identify useful information 4. Approach plant problems by formulating alternative solutions 5. List criteria for effective technical assistance	1. The importance of a systematic approach 2. The basic elements of troubleshooting 3. Troubleshooting Chart steps and elements in the Process of Troubleshooting 4. The importance of alternatives 5. Importance of final troubleshooting steps 6. Criteria for effective technical assistance	1. Use outline and slide key 2. Maximize student discussion and involvement	1. Slide series and key 2. EPA Manual, "Evaluating the Performance of Wastewater Treatment Plants" 3. Inspection checklist, Student Notebook, page ET-2 4. Chart, the Process of Troubleshooting 5. Student Notebook, page ET-9

ELEMENTS OF TROUBLESHOOTING

Lesson Plan – Subdivision 1 **Time: 45 Minutes**

Title: Attitudes and Human Behavior in Troubleshooting

Instructor Objectives: To present and illustrate to the class the proper attitudes and elements of human behavior required for effective troubleshooting.

Student Objectives: As a result of this lesson subdivision, students will be able to do the following:

1. Define Troubleshooting.
2. Relate the attitudes and human behavior characteristics of troubleshooting to their own jobs and their job performance.
3. Understand troubleshooting as applied to wastewater treatment plants.
4. Discuss the role of troubleshooters in dealing with plant operators and plant problems.
5. Differentiate between human and technical skills in troubleshooting.
6. Describe the potential goals involved in troubleshooting treatment plant problems.
7. Compare positive and negative types of troubleshooter behavior, particularly in dealing with plant operators.
8. Discuss characteristics of good troubleshooter behavior.

Training Materials:

Slide series of 6 word slides, and key

Troubleshooting dialogues No. 1 and No. 2, scripts provided (pages ET 1-9 thru ET 1-12).

Student Notebook page ET-1, notes on Troubleshooter Behavior.

Classroom Set-up:

A normal classroom set-up will be required.

Students should be seated with their student groups.

35 MM carousel slide projector with remote controls

Large screen (8 ft x 10 ft)

Chalkboard or easel

Pointer

Subdivision Schedule

Within the 45 minute time period, the following schedule should be observed in presenting the lesson plan outline.

Time	Subject
0 - 5 Minutes	Purpose and Objectives of lesson
5 - 15 Minutes	The nature of troubleshooting
15 - 35 Minutes	Troubleshooter behavior – illustrative Dialogues
35 - 45 Minutes	Characteristics of Good Troubleshooter Behavior

Subdivision Approach

The instructor is to rely upon the lesson outline, using the slide series and key. Student discussion is to be encouraged and stimulated. Specifically, the approach to be used is as follows:

Section

1. Follow outline, using one word slide.
2. Using outline and word slides, maximize class discussion and input.
3. Follow instructions to set up the presentation of two Troubleshooting Dialogues.
    - Select participants for dialogues
    - Introduce dialogues by reading "situation"
    - Participants present dialogues using prepared scripts
    - Instructor leads class discussion to analyze the dialogues.
4. Lead class discussion on good troubleshooter behavior. Have selected student record student input on chalkboard.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
I. Purpose and Objectives of Lesson (5 Minutes)	
A. Definition of Troubleshooting – Troubleshooting is the practice of problem solving – as applied to an existing facility in use and experiencing operational problems which affect its performance.	Guide: This definition may be given in "informal" terms, i.e. paraphrased, and discussed with the students.
1. "DEFINITION OF TROUBLESHOOTING" Troubleshooting is – the practice of problem solving Applied to an existing facility in use, and experiencing operational problems which affect its performance!	SLIDE ET-1 (word)
B. Troubleshooting treatment plant problems is being emphasized by EPA and the states – because of the Survey and the reasons discussed in the introductory Overview lesson.	Guide: If instructor needs more background, refer to lesson plan, Overview, Subdivision 3, "The Significance of Plant O&M."
C. Purpose of this lesson – To highlight the essential elements of troubleshooting, including 1. Necessary attitudes and human qualities 2. Necessary skills and technical qualities 3. A process for systematic troubleshooting	
D. Objectives of lesson – in terms of students' job performance. It is hoped that this lesson will enable students to: 1. Improve their troubleshooting skills 2. Appreciate the human qualities involved 3. Be more effective in assisting operators in solving plant problems. 4. Provide more useful technical assistance.	

LESSON OUTLINE

II. The nature of troubleshooting as applied to wastewater treatment plants (10 Minutes)

A. Troubleshooting is a *process* — not just a simple problem-solution activity.
   1. Troubleshooting may require repeated visits over a period of time.
   2. Troubleshooting often cannot produce a single "right" answer, instead it provides an *approach* to solving problems.
   3. The role of the troubleshooter is *indirect*, he is there to *assist* the operator.

"SOLVING TREATMENT PLANT PROBLEMS"

OPERATOR	TROUBLESHOOTER
Direct control over plant operations	Indirect role Uses experience to ASSIST

   4. Troubleshooting depends upon a troubleshooter's human *and* technical skills. A troubleshooter must be able to relate to both
      a. the plant and its processes
      b. the operator and his personnel

"TROUBLESHOOTER'S RELATIONSHIPS"

OPERATOR	PLANT
Human Skills:	Technical Skills:
Attitude	Experience
Judgment	Process control
Sincerity	Logic
Friendliness	Technical "know-how"

B. Successful troubleshooting requires knowledge of the facility being assisted, the people, the situation, and the specific troubleshooting goals.
   1. In order to have this understanding, a troubleshooter often has to "do his homework" before attempting to provide assistance.

KEY POINTS & INSTRUCTOR GUIDE

Guide: Encourage class discussion of the points brought out in this section.

Guide: Use slide ET-2 to illustrate.

SLIDE ET-2 (word)

Guide: Use slide ET-3 to illustrate

SLIDE ET-3 (word)

Guide: Ask class for discussion on other skills that may apply.

Guide: Illustrate this point with slide ET-4.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
2. "FOR EACH PLANT – TROUBLESHOOTERS MUST UNDERSTAND" • Plant organization – relationship of personnel • External community conditions • Past plant performance • Plant operations and processes • Environmental and regulatory requirements – EPA, State and Local	SLIDE ET-4 (word)
3. Troubleshooting activities in a treatment plant may be geared toward a variety of goals. Troubleshooters should have each of these goals in mind, including:	Use Slide ET-5 to illustrate
"TROUBLESHOOTING GOALS" • Repairing breakdown or immediate problem • Preventing reoccurrence of problem • Improving long-run O&M • Upgrading overall plant efficiency	SLIDE ET-5 (word)
4. In short, troubleshooters must apply a variety of tools, skills, and tricks.	Use Slide ET-6 to illustrate
"TROUBLESHOOTERS ARE" • Investigators • Problem solvers • Mechanics • Psychologists • Assistants	SLIDE ET-6 (word)
III. Troubleshooter Behavior Illustrative Dialogues (20 Minutes) A. Instructions on Presenting dialogues 1. Select 3 persons in advance to participate – either faculty, or if necessary, students 2. Assign roles to each: Bob, Joe, Tom 3. Have participants review the dialogues once or twice. They may read the script while presenting the dialogues. Some ad-lib may be permitted, as long as the essence of the dialogues is not lost. No "overacting" allowed.	Guide: Two dialogues are to be presented to the class to illustrate two types of troubleshooter behavior. Each dialogue is to be analyzed by the class. Note: Instructor must reproduce copies of dialogue scripts in advance of lesson for use by participants.

LESSON OUTLINE

B. Present Dialogue No. 1 to the Class (10 Minutes)

1. Call "Joe" and "Bob" to the front of the room with their scripts
2. Read the following opening statement on the "situation" to the class
3. Situation: Dialogue No. 1

   Joe is an engineer in the field office of the state water pollution control agency. He has two years of experience out of college, and has had graduate level courses in Sanitary Engineering.

   Joe is assigned by his office to inspect and evaluate a 10 mgd activated sludge plant with a normal domestic waste flow of 6 mgd. The plant has an excellent lab. The plant effluent has not been meeting standards, and has been turbid. Septic odors are evident in proximity to the aeration basins.

   Upon entering the plant, Joe meets Bob, who is the chief operator on the day shift. Before this plant was built, Bob was the operator of a 1.5 mgd trickling filter plant operated by the city. He is 53 years old, and has been in wastewater treatment for 22 years. He is a night school graduate of high school, and a certified operator. Until this inspection, Joe and Bob had not met before.
4. Have "Joe" and "Bob" present dialogue No. 1
5. Analysis of dialogue No. 1. At the completion of dialogue No. 1, ask the class to comment on characteristics of Joe's behavior that they observed.

   Joe's characteristics:

   a. Attitude – he made it sound like he was doing the operator a favor by being there.

   b. Put down the plant – said no one gives a damn about it.

   c. Unfamiliar with operator – probably didn't know he was there for a long time.

   d. "Know-it-all" – didn't want to review the data and the plans.

KEY POINTS & INSTRUCTOR GUIDE

Situation: Dialogue No. 1 Instructor to read to class.

Class discussion during this analysis should be stimulated by the instructor.

For the instructor's guide, some of the characteristics of Joe's behavior are listed.

LESSON OUTLINE

e. Not investigative said all activated sludge plants are alike.
f. Poor attitude toward operators blames them for all plant problems.
g. Threatens strong legal action instead of stressing cooperation.
h. Does not consider alternatives "knows it all" sees one and only one right solution to the problem.
i. Did not follow operator's suggestions.
j. Tried to impress the operator with his Master's degree.

6. Following this analysis ask the class if they've ever met someone like Joe.

C. Present Dialogue No. 2 to the class (10 Minutes)

1. Call "Tom" and "Bob" to the front of the room with their scripts
2. Read the following opening statement on the "situation" to the class.
3. Situation: Dialogue No. 2

Tom is on the staff of the field office of the State Water Pollution Control Agency. He has a degree in chemistry, and twelve years of experience. His experience includes inspecting wastewater treatment plants.

He is assigned by his office to inspect and evaluate a 10 mgd activated sludge plant with normal domestic waste flow of 6 mgd. The plant has an excellent lab. The plant effluent has not been meeting standards, and has been turbid. Septic odors are evident in proximity to the aeration basins. (Same plant as before).

Upon entering the plant, Tom meets Bob who is the Chief Operator on the day shift. Before this plant was built, Bob was the operator of a 1.5 mgd trickling filter plant operated by the city. He is 53 years old, and has been in wastewater treatment for 22 years. He is a night school graduate of high school, and a certified operator. Until this inspection, Tom and Bob had not met before.

KEY POINTS & INSTRUCTOR GUIDE

Situation: Dialogue No. 2
Instructor to read to class.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
4. Have "Tom" and "Bob" present dialogue No. 2	
5. Analysis of Dialogue No. 2. At the completion of dialogue No. 2, ask the class to comment on characteristics of Tom's behavior that they observed.	Guide: Encourage class discussion.
Tom's characteristics: a. Shows interest — has wanted to see the plant. b. Sympathizes with operator — talks about other plants with problems. c. Shows knowledge and appreciation of operator. d. Did his homework — looked at plans and data. e. Offers encouragement and assistance to the operator. f. Plans to share troubleshooting experience with the operator. g. Recognizes the operator's experience. h. Is investigative — looks for cause of the problem. i. Stresses process control tests j. Will assist operator in setting up process controls. k. Takes a personal interest in the operator — develops a good relationship.	For instructor's guide.
	At the end of the 20 minutes on the dialogues, lead directly into the next section.

SCRIPT NO. 1

TROUBLESHOOTING DIALOGUE NO. 1

Joe: Hi – I'm Joe Smartass. My boss in District 3 tells me you've been having problems, so he sent me up here. I really didn't want to come 'cause I'm falling behind in writing permits – but he told me I have to try to help you out.

Bob: Nice to meet you, Joe. I sure hope you can help.

Joe: It's no wonder the plant is fouled up – I've heard they've been having problems up here for thirty years and that no one in this town really gives a damn about clean water anyway.

Bob: How about a cup of coffee while we go over some of the plant records and plans.

Joe: Well, thanks – but there's no need to pour over a lot of plans and data. These activated sludge plants are all alike. They're never operated the way they are supposed to be anyway.

Let's see, this one was designed by Shovel & Snow, wasn't it? They do a pretty good job – I once attended an advanced treatment symposium given by their engineers. Trouble is the operators around just aren't smart enough to run these plants the way good old S & S designs them.

Bob: Well . . . .

Joe: We don't need to look at the lab data – we know that you haven't been meeting standards – in fact, I've been meaning to talk to you about that – if you don't do something we're going to have to take some pretty strong action – our lawyers are just itching to get their hands on a couple of towns like this. You know, with this new law the people running these plants are subject to criminal prosecution. It's about time we got tough with some of these yokels.

Bob: Let's take a walk around the plant, Joe, there may be a few things you can help on.

Joe: No need for that. 90 percent of these plant problems are caused by sludge bulking. Why – I've seen three plants like that myself. Hell, even doctors can't tell what's wrong with a patient to 90% accuracy. That's what's so good about being a Sanitary Engineer – you don't need to carry malpractice insurance – you're usually right the first time. Anyway – if you wipe out the bugs they can't sue you.

Troubleshooting Dialogue No. 1 (continued)

Bob: Are you sure you know what's going on? What about checking the sludge and the aeration tanks?

Joe: Oh – they're all the same. Now I've got this troubleshooting manual from EPA that tells you what to do for bulking. Here – follow this and see if things get better in a few days. I've got to split so I can get to my graduate course in advanced microbiology. Boy, I can't wait 'til I get that master's degree. Then I'll really be able to help old timers like you.

-Curtain Closes-

SCRIPT NO. 2

Elements of Troubleshooting **Subdivision 1**

TROUBLESHOOTING DIALOGUE NO. 2

Tom: Hi – I'm Tom Fixit. I've been hoping to get a chance to get up here to meet you and to take a look at this plant, but until now they've had me doin' other things. I've heard you've been havin' some problems.

Bob: It's nice to meet you, Tom. I sure hope you can help.

Tom: Well, of course you're not the only one having problems these days. What with the rains we've had, almost all of the plants in the valley have been overloaded one way or another. I can't wait until we get some of these sewer problems fixed up, so that these plants can operate the way they're supposed to.

Bob: How about a cup of coffee while we go over some of the plant records and plans?

Tom: Well, thanks, Bob. You ran that old trickling filter plant, didn't ya, that was something back in those days. An operator had to be jack-of-all-trades. I really admire a guy that can do it all.

Bob: Well, things ain't like they used to be, but I'm tryin' my best with this new plant. It sure looks pretty, but sometimes I wonder about the design. Sometimes this plant just doesn't do what it's cracked up to do.

Tom: I know. Before I came over I took a look at the plans, and at some of the monitoring data you've been sending in, and I think you're right. This plant could sure use a lot more flexibility than it has. Some of those textbook engineers that design these plants just don't know what it's really like out there, with the loads varying and the infiltration, and the heavy rainfall, and all the other problems that the operators have. I think, though, looking at the plans, that you and I can figure out a couple of ways in which to get this plant running a little more smoothly, and also letting it take care of some of that stormflow that's been comin' in here.

Bob: Well, I'm glad you said that. I've been looking forward to getting some help. We've put in some requests for more money from downtown so that we can hire a consultant to help us out, but the money hasn't been made available yet. Anyway, I'm not sure we know anyone who could really help us to do a better job at the plant.

Troubleshooting Dialogue No. 2 (continued)

Tom: Well, after all, you're the guy that knows this plant the best, so I think that with a little of my experience and your knowledge of this plant, we probably have all the help we need right here. Why don't we go for a walk around the plant, and you can show me some of the areas where you've been having problems, and some of the things about the plant that we can't get off of the plans. Also, why don't you bring your chemist, I hear he's a pretty good old boy, and we can put him to work running some tests. By the way, what kinds of process control tests have you been doin'?

Bob: Well, I'll tell you the truth, we've been so busy runnin' our effluent samples, and checkin' some of the industrial wastes that have been comin' into the plant, that we haven't had much time for process control tests. Furthermore, George, he's the chemist you know, He's not real familiar with those tests. He's a chemist from way back and doesn't really know much about runnin' a plant.

Tom: Well, before I go we'll try to fix you up with a schedule of process control tests. They're really not hard to do, and with the kind of information they give you, you'll be able to do a heck of a better job running this plant.

Bob: That sounds alright with me. Just so long as I know what's happening, so I can make sure that I follow through and do the things that you're able to come up with. Well, are you ready for a tour around the plant?

Tom: In a few minutes, how about a second cup of coffee. I understand you have some great fishin' not too far from here . . . you're goin' to have to tell me all about it.

-Curtain Closes-

LESSON OUTLINE

IV. Characteristics of Good Troubleshooter Behavior (10 Minutes)

A. Instructions:

1. Ask one student to go to the chalkboard as the recorder.
2. Ask students to suggest characteristics of "good" troubleshooter behavior – i.e., behavior they feel is beneficial in troubleshooting plant problems.
3. The instructor can set the stage asking the students to imagine that they are a chief in the agency's field office, about to interview new employees to be field staff and troubleshooters. What characteristics would they look for?

B. Possible characteristics of Good Troubleshooter Behavior:

1. Thorough and open communication
2. Ability to listen and understand
3. Honesty and sincerity
4. Respect for the operator
5. Understands his own limitations – knows when to get help.
6. Assists operator – works through mutual participation
7. Judgment and common sense
8. Interest in the operator's problems.

KEY POINTS & INSTRUCTOR GUIDE

Guide: This section should encourage maximum class participation.

Have students suggest good troubleshooter characteristics, and why. Recorder should record the suggestions.

Guide: This list should be used as the instructor's reference.

This list is by no *means* complete. –

Go on to Subdivision 2.

At the end of this subdivision – refer students to Notebook page ET-1 "Notes on Troubleshooter Behavior," available for their reference.

Lesson Plan – Subdivision 2 **Time: 45 Minutes**

Title: The Process of Troubleshooting

Instructor Objectives: To present, illustrate and discuss a systematic Process of Troubleshooting that can be used to approach operational problems at wastewater treatment plants.

Student Objectives: As a result of this lesson subdivision, students will be able to do the following:

1. List the basic elements of troubleshooting.
2. Discuss and employ the chart, the Processs of Troubleshooting.
3. Identify and utilize the initial steps in the process of troubleshooting.
4. List the types of plant information to be reviewed by troubleshooters.
5. Locate information on sampling, testing, and analyzing for plant data.
6. Identify useful sources of information for troubleshooters.
7. Approach plant problems by formulating alternative solutions.
8. Identify types of corrective actions to take, and the long run implementation of those actions.
9. Carry out the very important final steps in the Process of Troubleshooting.
10. List the criteria for producing an effective technical assistance effort.

Training Materials:

Slide series of 12 word slides, and key.
EPA Manual "Evaluating the Performance of Wastewater Treatment Plants"
Inspection Checklist, Student Notebook page ET-2
Chart, the Process of Troubleshooting, Student Notebook.
    Chart also to be displayed at front of classroom.
"Sources of Information for Troubleshooters," Student Notebook page ET-9.

Classroom Set-up:

A normal classroom set-up will be required.
Students should be seated with their student groups.
35MM carousel slide projector with remote controls.
Large screen (8 ft x 10 ft)
Chalkboard or easel
Pointer

Subdivision Schedule:

Within the 45 minute time period, the following schedule should be observed in presenting the lesson plan outline.

0 - 5 Minutes	The systematic nature of troubleshooting
5 - 15 Minutes	Elements of Troubleshooting – Initial Steps
15 - 20 Minutes	Formulating alternative solutions
20 - 30 Minutes	Steps 3, 4, and 5, Elements of Troubleshooting
30 - 45 Minutes	Summary of discussion

Subdivision Approach:

The instructor is to follow the lesson outline, using the slide series and key.

This lesson depends upon *student discussion,* and the instructor serving as a catalyst to generate student discussion.

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

I. The systematic nature of troubleshooting (5 Minutes)

A. Troubleshooting Involves
   1. Relationships with operators
   2. Investigation and analysis of problems
   3. Understanding the processes of waste treatment

B. Troubleshooting must be systematic – to enable the troubleshooter to use his most effective tools in the precious time available to him.

Key Point: The importance of a systematic approach.

C. There is no formula for troubleshooting – but there are guides available that can help, such as
   1. EPA Manual "Evaluating the Performance of Wastewater Treatment Plants"
   2. Inspection checklists
   3. Forms – such as EPA Form 7500-5 "Report on Operation and Maintenance of Wastewater Treatment Plant"

Note: One such checklist is included in Student Notebook Pages ET-2 thru ET-7.

D. Regardless of what guides are used, the basic elements of a troubleshooting approach are as follows:

"BASIC ELEMENTS OF TROUBLESHOOTING"

SLIDE ET-7 (word)

- Review of plant conditions
- Communication and observation
- Analysis and testing
- Formulation of alternative actions
- Corrective actions – trial and error
- Long range implementation
- Monitor, document, and follow-up

E. To illustrate these elements, this course uses a chart called "The Process of Troubleshooting." This chart:
   1. Will be used throughout the course in each lesson.
   2. Demonstrates the systematic nature of troubleshooting.
   3. Is not a formula or list to follow – experienced troubleshooters develop their own approach.

Refer to chart in Student Notebook, section on Elements of Troubleshooting.

Also – chart may be displayed in front of classroom for other instructors to refer to.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
F. Questions and discussion on the systematic nature of troubleshooting.	
II. Elements of the Process of Troubleshooting – initial steps – analyzing and learning (10 Minutes)	Note: This section relates to line 1 of the Chart, The Process of Troubleshooting
A. "THE PROCESS OF TROUBLESHOOTING ANALYZING AND LEARNING" a. Begin troubleshooting b. Review information c. Visit plant d. Determine data needs e. Analyze, sample, and test f. Process test	SLIDE ET-8 (word) Guide: This slide is used to illustrate the initial troubleshooting steps.
B. Step a. – Begin Troubleshooting "BEGIN TROUBLESHOOTING" Possible Circumstances of Troubleshooter Entry Into Plant • Part of routine inspection • Request by plant operator • Complaint from citizens • Violation of permit conditions	SLIDE ET-9 (word) Key Point: The troubleshooting approach may depend on the circumstances by which a troubleshooter visits a certain plant. Slide ET-9 outlines some of the possible initial circumstances
C. Step b. – Review Information List of Possible Types of Plant Information for Instructor Reference: 1. Plans and design of plant 2. Daily log, including maintenance and breakdowns 3. Results of process control tests 4. Results of NPDES monitoring 5. Other?	Guide: Ask class to suggest the kinds of information a troubleshooter should review, and why.

LESSON OUTLINE

D. Step c. – Visit Plant
   "VISIT PLANT – MEET AND LISTEN"
      Observe and Review

   Who should you meet?
   Who should you listen to?
   What should you observe?
   - Why??

E. Step d. – Determine Data Needs
   1. Do we know what problems exist?
   2. Do we know their causes?
   3. Once data needs are determined, the troubleshooter and operator can begin to carry out the next two steps in the process.
   4. Which samples, tests, and analyses to make
   5. What process tests to run

F. Step e. – Analyze – Sample and Test
   1. Students can consult EPA Manual "Evaluating the Performance of Wastewater Treatment Plants" for specifics –
      a. Chapter II – To compare plant performance to normal operating characteristics
      b. Chapter III – Sampling and testing program.
   2. Lesson on Laboratory Practices later in the course expands on the techniques of sampling and testing for process control.

G. Step f. – Process Test
   1. One of the most significant tools a troubleshooter has is to modify some elements in the treatment processes, and observe and test the effects.
   2. Many of the lessons in the course deal in depth with process tests.

H. Useful sources of information for Troubleshooters.
   1. In-plant information
      a. Plant log and records
      b. NPDES permit and monitoring data
      c. Plant O&M manual

KEY POINTS & INSTRUCTOR GUIDE

SLIDE ET-10 (word)

Guide: Student discussion of these topics should be encouraged, using this slide to probe student views.

Guide: Ask students to suggest the types of data that may be needed for troubleshooting.

Guide: Instructor should refer class to sources of information on Sampling and Testing.

Refer students to Notebook Page ET-9. "Sources of Information for Troubleshooters."

Guide: Review these sources briefly with the class.

LESSON OUTLINE

H. (continued from ET 2-5)

2. EPA Materials
    a. Inspection and evaluation forms
    b. Performance evaluation manual
    c. Case histories – plant performance
    d. Technology transfer and other technical information
3. Other technical materials
    a. State manuals and guidelines
    b. WPCF
4. Other persons who can be called for assistance
    a. The operator
    b. Other local people
    c. State specialists
    d. Federal specialists
    e. Operations consultants
5. Personal observations
    a. Plant personnel and operators
    b. Physical conditions of plant
    c. Working conditions
    d. Inter-personal relationships
    e. Management behavior
6. Analyses and tests
    a. Compare plant performance to normal operating characteristics
    b. Sampling and testing program
    c. Process modifications and testing

III. Elements of the Process of Troubleshooting – Formulating Alternative Solutions (5 Minutes)
"FORMULATING ALTERNATIVE SOLUTIONS"

a. Initial Opinion – do we know the cause?
b. Opinion – reasoning leads to alternatives
c. Alternatives – consider types and impact of each
d. Priority alternatives
e. Confirm – with whom?

KEY POINTS & INSTRUCTOR GUIDE

SLIDE ET-11 (word)

Guide: Use this slide to discuss the development of alternative solutions.

Key Point: Stress that there is often not one single right answer, that alternatives need to be considered, and the impact of each needs to be known.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
IV. Elements of the Process of Troubleshooting – Steps 3, 4, and 5 (10 Minutes)	
A. "ELEMENTS OF TROUBLESHOOTING" CORRECTIVE ACTIONS • Type of action to take • Purpose of action • Duration of the results • Effect of action • Should there be a combination of different actions for different purposes?	SLIDE ET-12 (word) Guide: Use this slide to discuss things to consider while recommending corrective actions.
B. "OBSERVE AND TEST" • Which tests to make • Evaluate the results • Compare results with prior performance • Are the desired results achieved? If not – select a different alternative	SLIDE ET-13 (word) Guide: Use this slide to discuss Step 4 in the Process of Troubleshooting.
C. "LONG RANGE IMPLEMENTATION" Types of Measures Possible • Process or flow changes • Chemical additions • Design modifications • Repair or replace equipment • Cleaning and maintenance • Management changes	SLIDE ET-14 (word) Guide: Use this slide to discuss possible types of troubleshooting measures that can be implemented.
D. "FINAL STEPS IN THE PROCESS OF TROUBLESHOOTING" • Monitor results • Document • Follow-up	SLIDE ET-15 (word) Key Point: Each of these steps is essential to the conclusion of a successful troubleshooting effort. They should be stressed.
E. Discussion Instructor should ask members of class who have had experience in troubleshooting whether or not this Process of Troubleshooting resembles the approach they have used.	Guide: Direct discussion around the students' own personal experiences.

LESSON OUTLINE

V. Summary and Discussion (15 Minutes)

A. As indicated early in the lesson, troubleshooting activities need to reflect troubleshooting goals.

"RESULTS SHOULD REFLECT GOALS"
Know What You're Trying to do!

- Solve immediate breakdown or problem
- Prevent reoccurrence
- Improve long-run O&M
- Upgrade plant performance

B. However, even with all of the right technical skills, positive human behavior by troubleshooters is needed to produce effective technical assistance to the man who needs it, the operator or plant superintendent.

"EFFECTIVE TECHNICAL ASSISTANCE IS"

- Accepted and understood by the operator
- Feasible, in both $ and manpower resources for the plant
- Within the plant capacity and design
- Of long range value to the plant
- ???

C. Summary

"TROUBLESHOOTING"

- Requires *human* and technical skills
- Needs *positive* human behavior
- Must be *systematic*
- Can be approached through the Process of Troubleshooting
- Must be *accepted* and *feasible*

D. Discussion and questions

KEY POINTS & INSTRUCTOR GUIDE

SLIDE FT-16 (word)

Guide: Suggest that by following the principles of the Process of Troubleshooting, these goals can be met.

SLIDE FT-17 (word)

Key Point: Without meeting these criteria, a good technical effort may be wasted.
VERY SIGNIFICANT

Guide: Use next slide to briefly summarize the lesson.

SLIDE FT-18 (word)

Use any remaining time for discussion and questions.

STUDENT NOTEBOOK MATERIALS

The following materials are included in section 2 of the Student Notebook ELEMENTS OF TROUBLESHOOTING. The notebook is distributed to students at the start of the course, and is available to them as a reference material throughout the course. Some of these materials are to be used by the instructor as an integral part of the lesson.

Index of Notebook Materials

Pages	Material	Use in Lesson
ET-1	Notes on Troubleshooter Behavior	Reference by instructor, Subdivision I
ET-2 thru 7	Inspection Checklists	Reference by instructor, Subdivision II
ET-8	Chart, The Process of Troubleshooting	Used by instructor throughout Subdivision II
ET-9	Sources of Information for Troubleshooters	Reference by instructor, Subdivision II

NOTES ON TROUBLESHOOTER BEHAVIOR

Definition of Troubleshooting:

Troubleshooting is the practice of problem solving – as applied to an existing facility in use and experiencing operational problems which effect its performance.

Troubleshooting is a Process Which:

1. May require repeated visits over a period of time.
2. Often cannot produce a single "right" answer.
3. Provides an *approach* to solving problems.
4. Requires an indirect role; a troubleshooter's job is to *assist* the operator.
5. Depends on human *and* technical skills.

Troubleshooting goals include:

1. Repairing breakdown or immediate problem.
2. Preventing reoccurrence of problem.
3. Improving long-run O&M.
4. Upgrading overall plant efficiency.

Troubleshooters are:

1. Investigators
2. Problem solvers
3. Mechanics
4. Psychologists
5. Assistants

Characteristics of Good Troubleshooter Behavior:

1. Thorough and open communication
2. Ability to listen and understand
3. Honesty and sincerity
4. Respect for the operator
5. Understanding his limitations – knowing when to get help
6. Assists the operator – works through mutual participation
7. Judgment and common sense
8. Interest in the operator's problems

INSPECTION CHECKLISTS*

RE-INSPECTION PREPARATION CHECKLIST

- Review past inspection reports
- Review as-built plant drawings
- Review plant flow diagrams
- Review plant performance records
- Review plant design parameters

ROUTINE INSPECTION CHECKLIST

The following items should be considered during a routine inspection:

- Plant site maintenance, including landscaping, fencing, and buffer zone
- Plant aesthetics, including odors, building maintenance, and painting requirements of outside visible structures
- Plant operation and maintenance records
- Plant staffing for operation and maintenance
- Plant laboratory, including equipment, test procedures, and staff
- Plant influent
- Plant effluent
- Equipment records
- Safety equipment
- Sampling locations, methods, and frequency
- Solids disposal, both grit and digested sludge
- Plant bypass frequency
- Infiltration inflow

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* This check list is reproduced from Appendix B, "Basic Elements of State/Federal Programs on Operation & Maintenance of Municipal Wastewater Treatment Facilities," CH2M HILL, report to U.S. EPA, 3 February, 1975

DETAILED INSPECTION CHECKLIST

The detailed inspection checklist outlined is based on unit operations. For each individual plant, consideration should be given only to those unit operations relevant to that specific plant.

GENERAL

Consider all items outlined on the "Routine Inspection Checklist."

SCREENING AND COMMINUTION

- Clean area
- Odors
- Storage of screenings
- Frequency of removal
- Maintenance of mechanical equipment

GRIT REMOVAL

- Amount of grit removed
- Amount of grit in other plant units
- Volatile solids in grit
- Maintenance of mechanical equipment
- Clean area
- Odors
- Adequate venting of grit chamber for enclosed areas; explosive or toxic gases
- Explosion-proof lights and other items in enclosed areas

SEDIMENTATION BASINS

- Clean area
- Safety railings
- Maintenance of mechanical equipment
- Odor problems
- Corrosion on metal and concrete
- Floating sludge or gas bubbles

- Frequency of scum removal and if scum is allowed to accumulate on scum barrier
- Raw sludge pump maintenance and cycling frequency
- Pressure gauges (are they provided on sludge pumps?) – this gives operation conditions and tells of stoppages in sludge lines
- Plugging in sludge lines and valves
- Raw sludge removal and percent solids content
- Percentage removal of SS and BOD

BIOLOGICAL TREATMENT UNITS

Trickling Filters

- Dosing performance
- Filter flies and odors
- Corrosion of piping
- Maintenance of equipment
- Clogging of nozzles
- Condition of filter media, that is, ponding
- Cleaning program of underdrains
- Performance of final clarifiers (similar to primary sedimentation outline)
- Frequency of sludge handling from high rate system, as it becomes septic faster than from standard system
- Recirculation volumes
- Condition of biological growth on filter media
- DO of effluent
- Icing of filter surface if inspection is performed in cold climatic regions

Activated Sludge Process

- Frothing in aeration tank
- Corrosion
- Maintenance of equipment such as blowers, filters, diffusers, air lines, sludge pumps, and scrappers
- MLSS in aeration tank
- Flow and concentration of return sludge
- DO in aeration tank
- Bulking sludge in final clarifiers
- Rising sludge in final clarifier
- Waste sludge flow
- Sludge depths in hoppers and cycling rates of the sludge pumps
- Condition of launders on final clarifier
- Sludge valves and lines for sign of plugging
- Final clarifiers for skimmings removal
- Safety measures, such as guard rails

CHLORINATION

- Chlorine requirements based on effluent chlorine residual requirements and coliform organisms
- Equipment maintenance and pipe corrosion
- Safety measures such as gas masks (cannister and self-contained breathing), separate ventilation of chlorine feed rooms, explosion-proof electrical fixtures to prevent corrosion, storage of chlorine cylinders, and capped valves on chlorine cylinders
- Check method and frequency of cleaning chlorine contact table

SLUDGE DIGESTION

- Raw sludge solids concentration
- Percent volatile matter in raw sludge
- Temperature ranges of operation
- Sludge pumps for operation and maintenance
- pH control
- Mixing and/or recirculation
- Safety measures
- Gas production
- Percent reduction of volatile matter for digesting process
- Quality of supernatant for volatile acids, alkalinity, BOD, SS
- Supernatant withdrawn and recycled back into plant headworks

SLUDGE CONDITIONING

- Process used, such as gravity, elutriation, pressure flotation, or chemical coagulation
- Proper lab tests conducted, depending on the process
- Equipment operation and maintenance
- Solids uniformity and grit
- Process efficiency
- Odors, oils, and greases
- Clean area

SLUDGE DEWATERING

- Process such as drying beds, vacuum filters, or centrifuges
- Equipment operation and maintenance
- Clean area
- Odors, oils, and greases
- Check that adequate laboratory tests are conducted depending on dewatering process used

SLUDGE DISPOSAL

- Process such as incineration, sanitary landfilling, or soil conditioner
- Equipment operation and maintenance
- Odor and storage area
- Clean area

EQUIPMENT (GENERAL)

- Operation and maintenance records of all major equipment
- Manufacturer's parts and operation and maintenance manuals of all major equipment
- Operation and maintenance of equipment according to manufacturer's recommendation
- Excessive downtime
- Preventive maintenance program
- Calibration of instruments
- Operation and maintenance of instruments

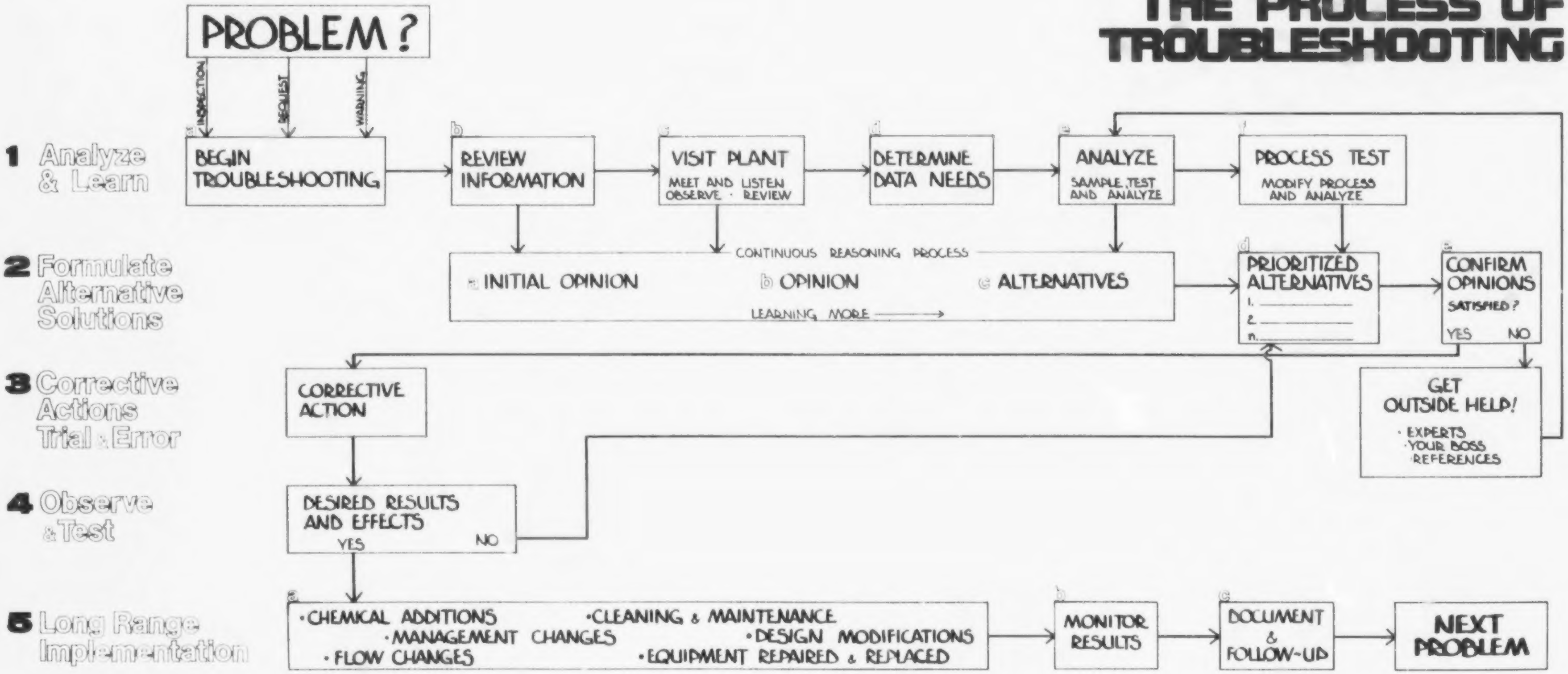
RECORDS (GENERAL)

- Availability at plant of as-built design drawings
- Availability of operational records
- Availability of laboratory records
- Data management procedures

STAFFING (GENERAL)

- Adequate staff available at facility for both the plant and laboratory
- Certification of plant operators
- Training programs for staff operators
- Shift requirements for operators
- Adequate administrative staff and supervision
- Adequate salaries for staff

THE PROCESS OF TROUBLESHOOTING


PROBLEM ?
INSPECTION
REQUEST
WARNING
1 Analyze & Learn
a BEGIN TROUBLESHOOTING
b REVIEW INFORMATION
c VISIT PLANT
MEET AND LISTEN
OBSERVE · REVIEW
d DETERMINE DATA NEEDS
e ANALYZE
SAMPLE, TEST AND ANALYZE
f PROCESS TEST
MODIFY PROCESS AND ANALYZE
2 Formulate Alternative Solutions
CONTINUOUS REASONING PROCESS
a INITIAL OPINION
b OPINION
c ALTERNATIVES
LEARNING MORE
d PRIORITIZED ALTERNATIVES
1.
2.
n.
e CONFIRM OPINIONS
SATISFIED ?
YES
NO
GET OUTSIDE HELP!
· EXPERTS
· YOUR BOSS
· REFERENCES
3 Corrective Actions Trial & Error
CORRECTIVE ACTION
4 Observe & Test
DESIRED RESULTS AND EFFECTS
YES
NO
5 Long Range Implementation
a
· CHEMICAL ADDITIONS
· CLEANING & MAINTENANCE
· MANAGEMENT CHANGES
· DESIGN MODIFICATIONS
· FLOW CHANGES
· EQUIPMENT REPAIRED & REPLACED
b MONITOR RESULTS
c DOCUMENT & FOLLOW-UP
NEXT PROBLEM

SOURCES OF INFORMATION FOR TROUBLESHOOTERS

1. In-plant information
    a. Plant log and records
    b. NPDES
    c. Plant O&M manual

2. EPA Materials
    a. Inspection and evaluation forms
    b. Performance evaluation manual
    c. Case histories – plant performance
    d. Technology transfer and other technical information

3. Other technical materials
    a. State manuals and guidelines
    b. WPCF

4. Other persons who can be called for assistance
    a. The operator
    b. Other local people
    c. State specialists
    d. Federal specialists
    e. Operations consultants

5. Personal observations
    a. Plant personnel and operators
    b. Physical conditions of plant
    c. Working conditions
    d. Inter-personal relationships
    e. Management behavior

6. Analyses and tests
    a. Compare plant performance to normal operating characteristics
    b. Sampling and testing program
    c. Process modifications and testing

LESSON – PRETREATMENT/PRIMARY TREATMENT

Instructor Overview of Lesson

Entry Level Behavior: Students will have had University training in Sanitary Engineering, waste treatment and/or related sciences or equivalent in experience and training. Some field experience in inspecting treatment plants, but none in operating waste treatment facilities.

As a prerequisite to this course, it is recommended that the student will be able to –

1. Identify treatment plant process units.
2. Describe treatment plant process units and equipment in technical terms.
3. Identify and explain the purpose of components of treatment plant process units, how they work and why they are important to the overall process.
4. Describe the normal operating procedures for treatment plant process unit components.
5. Identify when treatment plant process units are not operating properly.

Instructor Objectives: The principal instructor objectives for this lesson are:

1. To emphasize the importance of pretreatment processes in obtaining maximum performance from a wastewater treatment facility.
2. To stress visual observation as part of the Process of Troubleshooting, and its particular importance on the pretreatment area of a municipal wastewater treatment plant.
3. To present the basic elements of the Process of Troubleshooting as it relates to operational problems in primary treatment.

References: Note list of references included with Student Notebook materials.

Total Length of Lesson: 105 Minutes for 3 lesson subdivisions.

LESSON OVERVIEW

Subdivision Title & Time	Major Student Objectives	Key Points & Content	Approach	Materials
1. Pretreatment Key to Plant Performance 40 Minutes	1. List & identify purposes, functions and components of Pretreatment	1. Pretreatment is important in overall plant performance	1. Follow lesson outline using slide series	1. Pretreatment flow diagram, in Student Notebook
	2. Use Process of Troubleshooting to solve pretreatment problems	2. Troubleshooting actions are both immediate and long range	2. Students are given problem using slide and worksheets. Students solve problem in their student group	2. Slide series and slide key
	3. Be able to use and apply sewer use ordinances, and flow equalization	3. Sewer use ordinances and flow equalization help to prevent problems	3. Follow lesson outline; use slides and Notebook	3. Student Notebook problem and worksheet 4. Student Notebook: Sewer Use Ordinance and flow diagrams
2. The Eagle Eye of the Troubleshooter 20 Minutes	1. Recognize the value of visual observations	1. Using visual observations to quickly identify 10 pretreatment problems	1. Slides flashed on screen showing 10 different pretreatment problems. Students are to identify problem and record	1. Slide series of 14 slides
	2. Recognize pretreatment operational problems		2. Instructor then re-shows slides and reviews the problems presented	
3. Troubleshooting Primary Treatment 45 Minutes	1. Apply steps in the Process of Troubleshooting	1. Initial troubleshooting steps	1. Lesson is built around the steps in the Process of Troubleshooting Chart	1. Slide series and slide key
	2. List and identify for Primary Treatment normal operating characteristics, lab tests, common problems, causes, prevention, and corrective actions	2. Lab tests 3. Common Primary Treatment Problems 4. Implementing troubleshooting actions	2. Slides and slide key used to introduce topics 3. Heavy emphasis on student input	2. Process of Troubleshooting Chart 3. Student Notebook

LESSON – PRETREATMENT/PRIMARY TREATMENT

Presentation Options for Course Director

The 105 minute lesson, PRE/PRIMARY TREATMENT is an important introduction to the technical content of this course. It stresses the use of the Process of Troubleshooting to solve operational problems in treatment plant components, a theme which is repeated throughout the course. However, the lesson covers this technical material very briefly and in less detail than comparable material is covered in the following lessons.

The developers of the course have found, from the trial presentations, that students for whom this course is targeted do not require detailed review of the pretreatment and primary treatment processes, and generally find it to be a waste of time when more detail is provided. Additionally, students for whom this material would be new, and therefore useful, most likely are not experienced enough in waste treatment plant operations to benefit from the remaining lessons, or, in other words, do not really meet the entry level requirements of the course. Therefore, it is recommended that for the intended target students this lesson not be significantly expanded.

There are some alternatives for varying this lesson should they be considered appropriate by the Course Director.

Subdivision I - Pretreatment – Key to Plant Performance:

If more detail is desired on the pretreatment processes, the following alternatives may be used.

a. Section I, Introduction to Lesson and Purpose of Pretreatment may be expanded to any desired length, by using slides showing, and diagrams depicting, the various pretreatment process components. If this section is expanded, emphasis should be given to operational problems that occur in each component, and how those problems may be prevented and corrected.

b. If time permits, and an appropriate treatment plant is available, an inspection of various pretreatment components, and how they are maintained, could be instructive.

c. Section III – Sewer Use Ordinance. If it is anticipated that the students will have occasion to assist municipalities in the development of sewer use ordinances, this section could be expanded to suit the students' needs. The sample ordinance in the Student Notebook can be reviewed in detail, or student groups can be assigned to develop their own sample ordinance with follow-up discussion conducted by the instructor.

Subdivision 2 – The Eagle Eye of the Troubleshooter:

This portion of the lesson has maximum impact as a quick student exercise, and should remain as is.

Subdivision 3 – Troubleshooting Primary Treatment:

Although it is not recommended, Section III, Troubleshooting Problems in Primary Treatment can be expanded should the Course Director believe that more emphasis be given to Primary Treatment. Sixty minutes would be a reasonable maximum length of time for this section.

PRETREATMENT/PRIMARY TREATMENT

Lesson Plan – Subdivision 1 **Time: 40 Minutes**

Title: Pretreatment – Key to Plant Performance

Instructor Objectives: To emphasize the importance of pretreatment processes in obtaining maximum performance from a wastewater treatment facility. To present the basic elements of pretreatment, and how troubleshooting and preventing pretreatment problems can prevent operational problems in the treatment processes downstream in the plant.

Student Objectives: As a result of this lesson subdivision, students will be able to do the following:

1. Appreciate the importance of pretreatment processes in overall plant performance.
2. List the purposes and functions accomplished through pretreatment.
3. Identify the components of pretreatment at a wastewater treatment plant.
4. Follow a systematic approach in solving operational problems in pretreatment by applying the elements of the Process of Troubleshooting.
5. Recommend immediate and long term solutions to operational problems in pretreatment.
6. Identify opportunities for the use of a sewer use ordinance.
7. Assist municipalities in preparing, using, and enforcing sewer use ordinances.
8. List and describe the purpose and benefits of flow equalization.
9. Apply methods of equalizing treatment plant inflows to actual treatment plant situations.

Training Materials:

Flow diagram for pretreatment processes, Student Notebook page PR-1

Slide Series (6 slides) with slide key.

Student Notebook pages PR-2 and PR-3 for problem presented in Section II, as follows:

1. Page PR-2 Plant information and background
2. Page PR-3 Problem worksheet

Sample Sewer Use Ordinance, Pages PR-4, thru PR-16, Student Notebook

Flow diagrams for flow equalization, Student Notebook pages PR-17 and PR-18

Classroom Set-up:

A normal classroom set-up will be required. Students should be seated with their student groups, in order to work in groups on an assigned problem in Section II.

35 mm carousel slide projector with remote controls

Large screen (8 ft x 10 ft)

Chalkboard or easel

Pointer

Subdivision Schedule:

Within the 40 minutes time period, the following schedule should be observed in presenting the lesson plan outline.

TIME	SUBJECT
0 – 10 Minutes	Introduction and purpose of pretreatment
10 – 20 Minutes	Student group problem solving "Applying the Process of Troubleshooting"
20 – 30 Minutes	Class discussion on student group problem
30 – 35 Minutes	Sewer Use Ordinance
35 – 40 Minutes	Flow equalization

Subdivision Approach:

This lesson subdivision utilizes a variety of approaches by the instructor, designed particularly to involve students in problem solving in groups by using the Process of Troubleshooting.

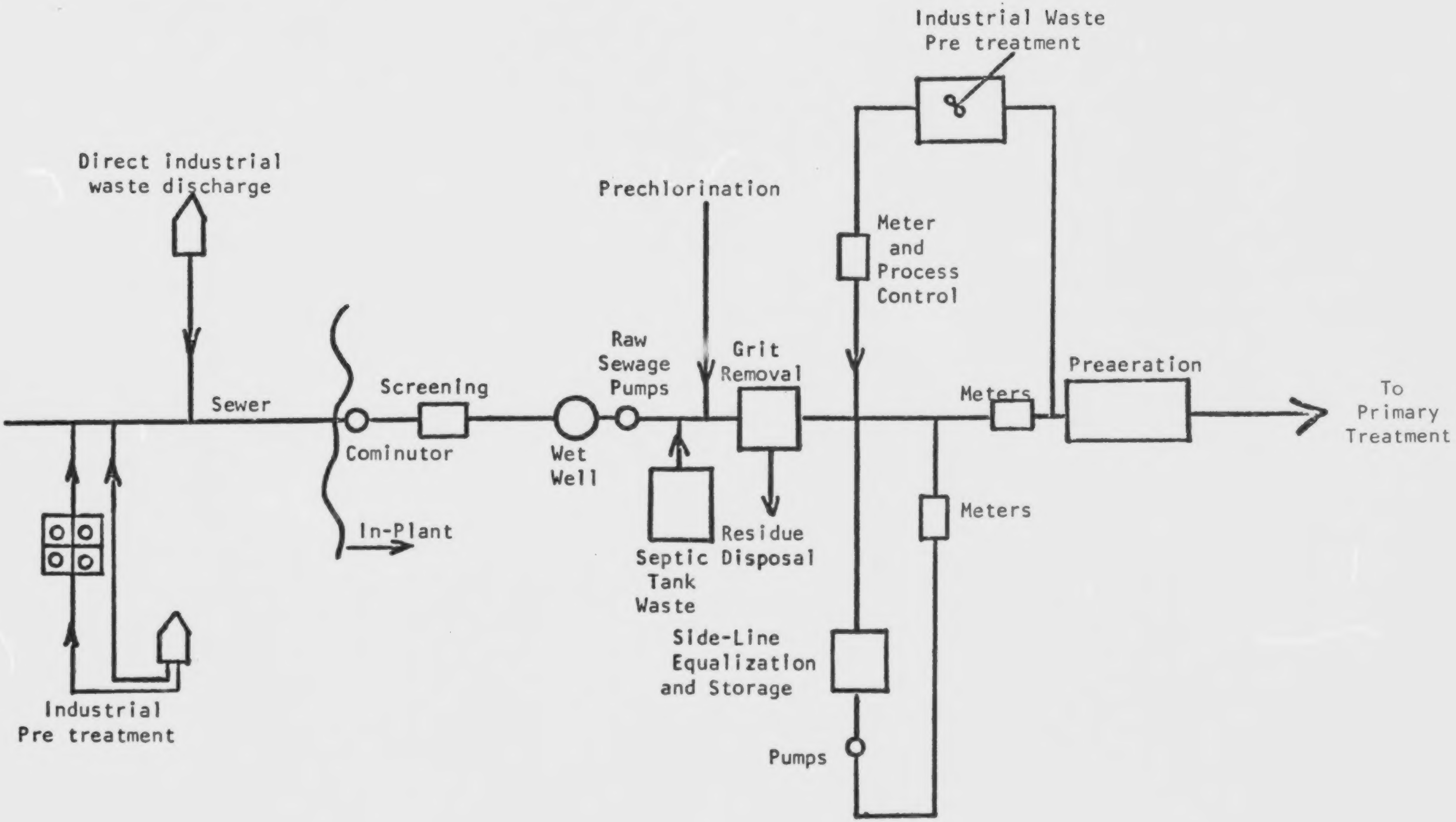
Section I – Instructor is to rely upon the lesson outline, and on one slide and slide key.

Section II – Student groups are assigned a problem using materials provided in the Student Notebooks, and by viewing a slide which depicts the problem. Each member of the group is to participate in working on the problem. After 10 minutes, the instructor is to lead a class discussion on the nature, cause, and corrections to the problem depicted.

Section III – Instructor is to rely on lesson outline, slide series and slide key.

Section IV – Instructor is to use lesson outline, slide series and slide key, and flow diagrams provided in Student Notebook.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
I. Introduction to Lesson and Purpose of Pretreatment (10 Minutes) A. Lesson *objectives* 1. To present a treatment plant as a *system*, with operations at one process related to performance at others. 2. To make troubleshooters cognizant of the opportunity to *prevent* treatment plant problems and enhance performance by upgrading pretreatment operations. 3. To demonstrate the usefulness of the Troubleshooting Process in solving operational problems.	Guide: Instructor should introduce lesson by stating its objectives, and briefly relating lesson content to the course emphasis on troubleshooting.
B. *Purpose* of Pretreatment – To prepare inflowing wastewater in order to maximize downstream plant performance and waste removal. Pretreatment serves to: 1. Prevent the addition of materials to the influent which would pass thru the plant untreated. 2. Prevent the addition of materials which would injure or reduce the effectiveness of downstream processes. 3. Treat incoming wastes so as to upgrade downstream performance. 4. Minimize total capital and operating costs of sewage treatment.	Emphasize the importance of pretreatment processes in overall plant performance.
C. Some *functions* accomplished through pretreatment are: 1. Prevention of detrimental industrial wastes. 2. Treatment of industrial wastes to make them compatible with sewage. 3. Equalize and balance flows and hydraulic loadings. (flow equalization) 4. Reduce the size of coarse materials in influent. 5. Remove coarse materials from influent. 6. Eliminate or prevent anaerobic conditions. 7. Removal of grease, oil and scum. 8. Addition of chemicals to improve downstream treatability.	Guide: Note that Sewer Use Ordinances complement Pretreatment and are a very important device in accomplishing the purpose of Pretreatment.
D. Components of Pretreatment. 1. Briefly review the possible components of pretreatment in a treatment plant.	SLIDE PR-1 Refer students to diagram, Student Notebook page PR-1


Industrial Waste
Pre treatment
Direct industrial
waste discharge
Prechlorination
Meter
and
Process
Control
Raw
Sewage
Pumps
Grit
Removal
Preaeration
Screening
Sewer
Meters
To
Primary
Treatment
Cominutor
Wet
Well
Meters
In-Plant
Residue
Disposal
Septic
Tank
Waste
Side-Line
Equalization
and Storage
Industrial
Pre treatment
Pumps

Schematic Flow Diagram of
Pretreatment Process Components

LESSON OUTLINE

II. Applying the Process of Troubleshooting (20 minutes)

Show slide PR-2 on screen for 10 minutes while class works in student groups to solve problem.

At end of 10 minutes, call for class discussion on the problem.

The following are the *most likely* answers to the student problem. Note that in Troubleshooting there is not necessarily a single right answer to any problem.

A. LOCATION OF PROBLEM – Surface aerator at activated sludge aeration tank.

B. NATURE OF PROBLEM – Trash is being pulled from surface aerator turbine blades. This is happening because the turbine failed to keep the activated sludge aeration tank above zero D.O. under conditions in which the turbine normally supplied adequate tank oxygen.

C. CAUSE OF PROBLEM – The comminutor has been out of service for several months. An inquiry brought out the fact that a request for repair which was several months old went unheeded.

D. RECOMMENDED CORRECTIONS

1. Immediate correction – get the rags out of the system so that the aerators will function properly.
2. Repair the comminutor.
3. Improve screening at the front end of the plant in order to remove as much fibrous material as possible. Provide means for better screen cleaning.
4. Attempt to stimulate management decisions to provide adequate staff support for O&M. Provide training and assistance to improve process controls and lab capabilities.

E. Other Observations of Slide – Major Safety Problems

1. Man in very dangerous position
2. Cigar
3. No gloves or protective clothing

KEY POINTS & INSTRUCTOR GUIDE

SLIDE PR-2

Students are to be provided with the following materials in the Student Notebook:

A. Background and information on plant

B. Problem work sheet.

Pages PR-2, 3

(Lesson plan pages 1-7, 1-8)

Guide: Instructor should stimulate, not dominate discussion. Note that some students may not have seen this type of aerator.

Emphasize the following points during discussion of the problem:

1. That there are both immediate and long range actions that should be taken.
2. This problem demonstrates how downstream problems are caused by poor pretreatment.
3. That a thorough troubleshooting evaluation needs to be done in order to determine the deeper causes of this plant's problem.

GROUP ____________________

TROUBLESHOOTING PROBLEM – PRETREATMENT

PLANT BACKGROUND:

Plant flow is excess of 10.0 MGD

Essential equipment:

1. Pump station following a 2 inch bar screen
2. Comminutor in alternate channels
3. Pumps and preliminaries in a below grade pit
4. Primary treatment (2) clarifiers
5. Activated sludge surface aerators
6. Final clarifiers (2)
7. Anaerobic digesters

INITIAL OBSERVATION AND ANALYSIS BY TROUBLESHOOTER:

The plant facility has what appears to be adequate capacity but little versatility. Preliminary screen has an open channel behind it with poor facilities for cleaning screens and lifting screening out of the pit (approximately 25 ft down). Flow distribution, measurement, and control devices require real ingenuity and agility to master the situation and to achieve effective plant performance.

OBSERVATIONS ON MANAGEMENT BEHAVIOR:

1. Laboratory facilities and support appear weak.
2. The plant is understaffed.
3. Comments from staff lead you to believe that they get little support from city hall for their problems.
4. Staff appear to be hard working, and trying.
5. Records are scant except for the absolute minimum. There is little confidence in the records, except that they accurately show the plant to be not performing up to its design.
6. Process controls are limited. The staff is too busy just keeping the wastewater moving and solving problems like the one shown in the slide.

GROUP ____________________

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6. Process controls are limited. The staff is too busy just keeping the wastewater moving and solving problems like the one shown in the slide.

GROUP ______________________________ **Problem Worksheet**

TROUBLESHOOTING PROBLEM – PRETREATMENT

Student groups should answer the following questions.

1. What is the location of the problem shown in the slide?

2. What is the nature of the problem?

3. What is the most likely cause of the problem, based upon your knowledge of the plant as a troubleshooter?

4. What corrective actions would you recommend?

5. Do you see additional problems shown in the slide?

You have 10 minutes to complete this worksheet, at which time the problem will be discussed by the class.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
III. Sewer Use Ordinance (5 Minutes)	
A. One of the best tools in assuring effective pretreatment is a good sewer use ordinance. Troubleshooters have the opportunity of assisting communities in developing, using, and enforcing sewer use ordinances.	
B. "PURPOSE OF SEWER USE ORDINANCES" • Regulate use of public sewers • Control industrial wastes and incompatible pollutants • Set fee schedules	SLIDE PR-3 (word)
C. "TROUBLESHOOTER'S ROLE" • Advise community on need for ordinance • Review and evaluate possible ordinances • Assist in preparation, if asked • Assist in meeting with industries if asked	SLIDE PR-4 (word) Refer students to sample ordinance in Student Notebook – do not take the time to go into the details of the ordinance during the lesson. Page PR-4
IV. Flow Equalization (5 Minutes)	
A "PURPOSE AND BENEFITS OF EQUALIZATION" • Dampen hydraulic and organic overloads • Reduce the need for additional capacity • Improve treatment of efficiency	SLIDE PR-5 (word) Cite good reference for students on Flow Equalization – "Process Design Manual for Upgrading Existing Wastewater Treatment Plants," EPA, 1974. Chapter 3.
B. Refer to pages PR-17, 18, in Student Notebook on Flow Equalization reproduced from EPA Manual. Have class look at them briefly. 1. Flow diagrams of in-line and side-line equalization. (Notebook page PR-17) 2. Flow and BOD variation before and after equalization. (Notebook page PR-18)	Guide: These diagrams are found in instructor's lesson plan, pages PR-1 – 11, 12.

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

C. How to utilize equalization

1. Very few plants have built-in equalization, yet many have problems due to load fluctuations and excessive peak loads.
2. If troubleshooter can trace operational problems and process upsets to peaks in load, then he can recommend:
3. "FLOW EQUALIZATION METHODS"

SLIDE PR-6 (word)

- Use any available storage capacity
  spare tanks
  unused clarifiers
- Ponding or holding areas
- Vary levels in ditches or ponds to equalize flows.

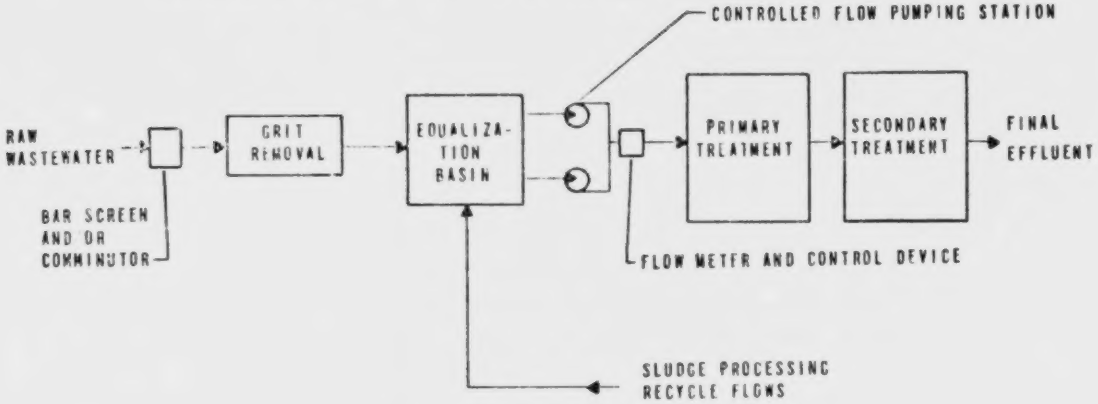
4. Design Considerations
   a. Troubleshooters must be aware of problems caused by improper design of flow equalization facilities, such as:
      1. Solids deposition
      2. Air requirements
      3. Scum removal
      4. Bank design
5. "Creative" troubleshooters can often devise means for flow equalization with the help of some available tankage, piping or hose, pumps and valves.

Guide: See if students can suggest other means of flow equalization.

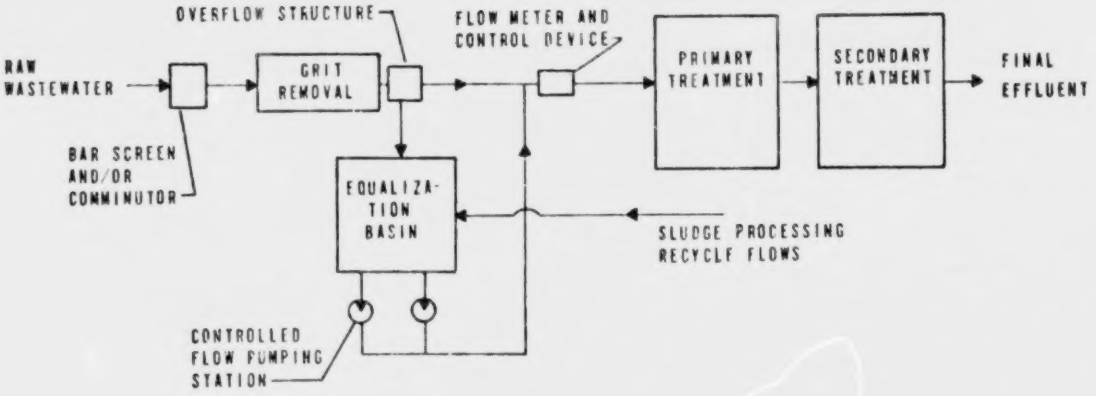
6. For flow equalization to be effective, accurate flow measurements are needed.

Reproduced from EPA "Process Design Manual for Upgrading Existing Wastewater Treatment Plants". Technology Transfer, October, 1974, Chapter 3.

SCHEMATIC FLOW DIAGRAMS OF EQUALIZATION FACILITIES


CONTROLLED FLOW PUMPING STATION
RAW WASTEWATER
GRIT REMOVAL
EQUALIZATION BASIN
PRIMARY TREATMENT
SECONDARY TREATMENT
FINAL EFFLUENT
BAR SCREEN AND OR COMMINUTOR
FLOW METER AND CONTROL DEVICE
SLUDGE PROCESSING RECYCLE FLOWS

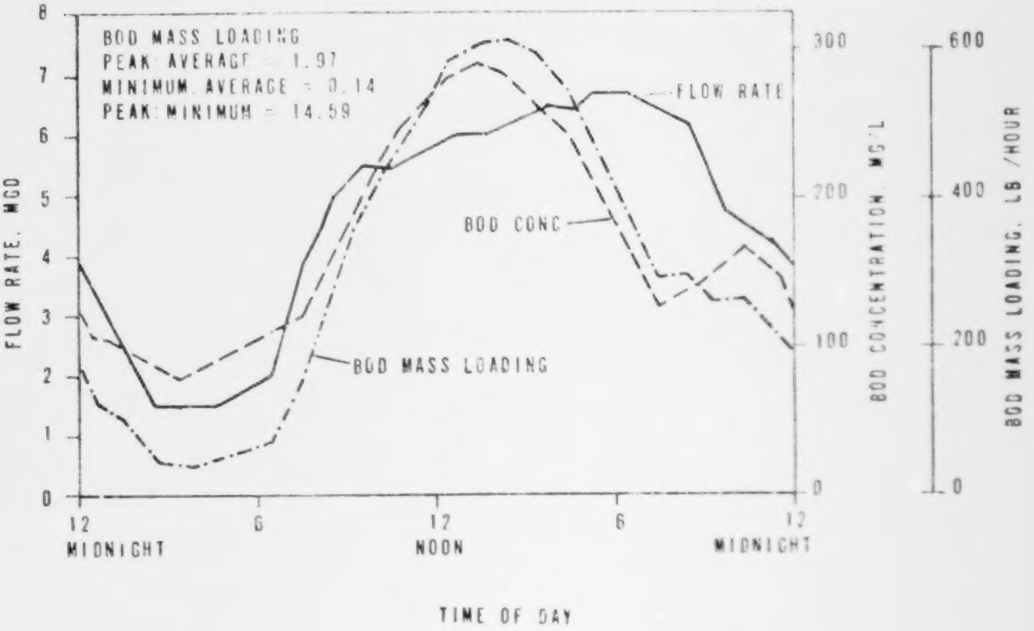
3-1a IN-LINE EQUALIZATION


OVERFLOW STRUCTURE
FLOW METER AND CONTROL DEVICE
RAW WASTEWATER
GRIT REMOVAL
PRIMARY TREATMENT
SECONDARY TREATMENT
FINAL EFFLUENT
BAR SCREEN AND/OR COMMINUTOR
EQUALIZATION BASIN
SLUDGE PROCESSING RECYCLE FLOWS
CONTROLLED FLOW PUMPING STATION

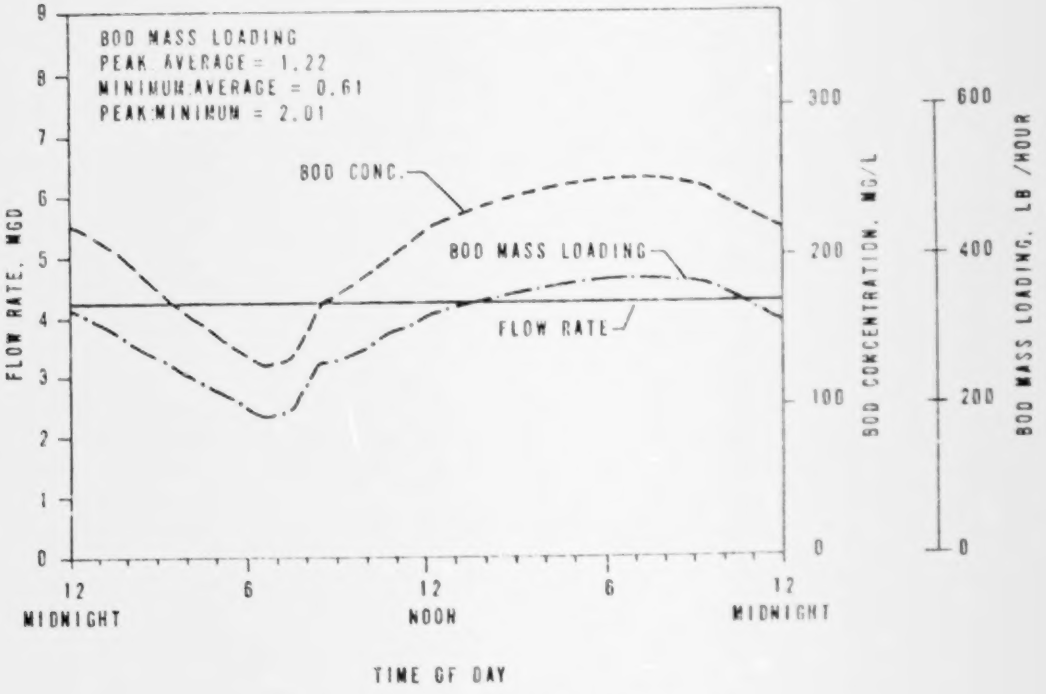
3-1b SIDE-LINE EQUALIZATION

Reproduced from EPA "Process Design Manual for Upgrading Existing Wastewater Treatment Plants". Technology Transfer, October, 1974, Chapter 3.

RAW WASTEWATER FLOW AND BOD VARIATION BEFORE EQUALIZATION



RAW WASTEWATER FLOW AND BOD VARIATION AFTER EQUALIZATION



PR 1-11 (Student Notebook page PR-18)

PRETREATMENT/PRIMARY TREATMENT

Lesson Plan – Subdivision 2 **Time: 20 Minutes**

Title: The Eagle Eye of the Troubleshooter

Instructor Objectives: To emphasize the need for and importance of visual observation as part of the Process of Troubleshooting, particularly at the pretreatment area of a municipal waste treatment plant.

Student Objectives: As a result of this lesson subdivision, students will be able to do the following:

1. Recognize the value of visual observation in troubleshooting problems at waste treatment plants.
2. Recognize some specific operating problems that occur in the pretreatment phase, and know how to deal with those problems.

Training Materials:

Series of 14 slides depicting problems at pretreatment processes

Slide key – and identification of problems represented by slides in the instructor's lesson plan

Classroom Set-up:

A normal classroom set-up will be required

Students should be seated with their student groups

35 mm carousel slide projector with remote controls

Large screen (8 ft by 10 ft)

Pointer

Subdivision Schedule:

Within the 20 minute time period, the following schedule should be observed in presenting the lesson plan.

TIME	ACTIVITY
0 – 10 Minutes	Instructor presents 10 problems to students in sequence through the prepared slide series.
10 – 20 Minutes	Slides are reshown, instructor reviews problems with class

Subdivision Approach:

Slides are to be flashed on screen, one minute allowed for each problem (some problems have one slide, others two slides, three slides).

Students are to try to identify

a. location of problem

b. general nature of problem

and record their answers in their notebooks.

After 10 minutes, instructor is to go back and re-show slides, specifying problem location and nature. Students are to keep score of their own success. At end of subdivision, instructor is to see who had the highest number of correct answers.

LESSON OUTLINE

I. Observing Problems in Pretreatment (10 Minutes)

For each problem, students are to try to identify

- A. Location of problem
- B. General nature of problem

and record their answers in their notebooks.

- C. Before showing slides, instructor should announce that this is obviously not representative of actual in-plant troubleshooting situations, where the troubleshooter –
  1. knows where he is
  2. can smell what's happening
  3. can talk to the operator
  4. can poke around
  5. can take samples and analyze
- D. Allow 1 minute for each problem:

KEY POINTS & INSTRUCTOR GUIDE

Flash slides on screen, one minute for each problem.

Problem	Instructor Should Announce	SLIDES
1.	These are views, taken 30 seconds apart, in opposite directions somewhere near the headgate.	PR-7 & PR-8 ½ minute each
2.	Slides show two different locations, same problem.	PR-9 & PR-10 ½ minute each
3.	This is one situation where the troubleshooter's nose would come in handy.	PR-11 1 minute
4.	No – This is not part of the lab test for a dishwashing detergent.	PR-12 1 minute
5.	Unlike many plant problems, this equipment appears to be in perfect working order.	PR-13 1 minute
6.	This location, outside of the plant, was not too far from the plant headgate.	PR-14 1 minute
7.	The flow shown here smells as bad as it looks.	PR-15 1 minute

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

Problem	Instructor Should Announce	
8.	Think of the operator's dismay when he tries to get this chain cleaned off.	PR-16 1 minute
9.	Three views, all taken while the grit elevator was in operation.	PR-17, PR-18, & PR-19 20 seconds each
10.	The fact that the operator was taking a horticulture course was completely incidental.	PR-20 1 minute

II. Problem Answers (5 Minutes)

Call on students to provide answers to each problem shown in slides in Part I.

Go back, very quickly flash the 14 slides in sequence, and review problem answers.

A. Guide to problem answers –

LOCATION	NATURE OF PROBLEM	PROBLEM
1. Plant inlet and grit chamber	Overflowing – pump surge problem, pump controls need adjustment.	(2 slides)
2. Various locations near headgate	Attempt (unsuccessful) to use masking agent to control odors from septic sewage.	(2 slides)
3. Headgate area	Red flow plus odor signified chicken packing waste – Troubleshooter on scene had no trouble finding feathers and fat as well.	(1 slide)
4. Headgate area	Foam signified serious industrial waste problem – in this case tannery waste.	(1 slide)
5. Screen	Operative by-pass gate – which was apparently used frequently	(1 slide)
6. Outside of plant – near sewer manhole	Construction by-pass pipe was still used as by-pass after construction.	(1 slide)
7. Grit chamber	Septic waste – with grease and gas bubbles rising. Sludge on bottom of chamber.	(1 slide)

LESSON OUTLINE		KEY POINTS & INSTRUCTOR GUIDE
8. Grit chamber	Chain drive collecting trash, showing inadequate screening upstream.	(1 slide)
9. Grit chamber	Turbulence, jet inlet and high flow prevented removal of grit. Note clean buckets.	(3 slides)
10. Grit chamber	Operator apparently gave up on removing grit – "It only fills up again anyway."	(1 slide)

PRETREATMENT/PRIMARY TREATMENT

Lesson Plan – Subdivision 3 **Time: 45 Minutes**

Title: Troubleshooting Primary Treatment

Instructor Objectives: To present the basic elements of the Process of Troubleshooting as it relates to operational problems in primary treatment. To stress the concept that there are often alternative actions that may be taken by a troubleshooter to correct operational problems at wastewater treatment plants.

Student Objectives: As a result of this lesson subdivision, students will be able to do the following –

1. Apply the initial steps in the Process of Troubleshooting.
2. Identify normal operating characteristics of primary clarifiers.
3. List the lab tests useful for process control and troubleshooting of primary treatment.
4. List and identify the most common problems in operating primary treatment facilities.
5. Identify the possible causes for abnormal primary treatment operations.
6. List and explain measures which can be used to prevent operational problems in primary treatment.
7. Identify alternative corrective actions to be used to solve operational problems in primary treatment.
8. Recognize and list the types of troubleshooting actions recommended for primary treatment.
9. Apply the final steps in the Process of Troubleshooting.

Training Materials:

Slide series with slide key

Process of Troubleshooting Chart

Student Notebook Tables on Raw Sludge Characteristics and Relationship to Other Processes, p PR-19

Troubleshooting Guide – Student Notebook, pp PR-20 thru 22

EPA Manual "Evaluating the Performance of Wastewater Treatment Plants," pp 59-63.

Classroom Set-up:

A normal classroom set-up will be required. Students should be seated with their student groups

35 mm carousel slide projector with remote controls

Large screen (8 ft by 10 ft)

Chalkboard or easel

Pointer

Subdivision Schedule:

Within 45 minute time period, the following schedule should be observed in presenting the lesson plan outline

TIME	SUBJECT
0 – 5 Minutes	Initiating the Process of Troubleshooting
5 – 10 Minutes	Lab tests
10 – 40 Minutes	Troubleshooting Problems in Primary Treatment
40 – 45 Minutes	Summary and Discussion

Subdivision Approach:

The instructor is to rely upon the lesson outline, and particularly upon the slide series and slide key.

This lesson subdivision is built around the Process of Troubleshooting Chart, and the instructor should refer to the chart frequently. The elements in the Process of Troubleshooting should be emphasized throughout the lesson.

In Section III, Troubleshooting Problems in Primary Treatment, the word slides and picture slides should be used to *identify* the topic, but the instructor should seek to maximize *class input* in discussing these topics.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
I. Initiating the Process of Troubleshooting (5 Minutes)	
A. "INITIAL STEPS IN THE PROCESS OF TROUBLESHOOTING" • Review known information • Visit plant: meet, listen, observe and review	SLIDE PR-21 (word) Guide: Emphasize steps in the Process of Troubleshooting
B. "LEARN HOW THE PLANT NORMALLY OPERATES" • Flows, load and balance • Removal efficiency • Sludge handling • Maintenance, and condition	SLIDE PR-22 (word)
C. "PRIMARY TREATMENT — NORMAL OPERATIONS" The following slides show some aspect of normal or abnormal operations of primary clarifiers that would be of interest to troubleshooters. Run through these slides briskly.	SLIDE PR-23 (word)
D. Are flows evenly distributed to all of the clarifiers?	SLIDE PR-24 depicting equal flows influent to clarifiers.
E. Are overflow weirs kept clean and at equal elevations?	SLIDE PR-25 shows operator cleaning weir of rectangular tank.
F. Are routine inspections and preventive maintenance practiced? Is the equipment in a good state of repair?	SLIDE PR-26 shows a maintenance person (Texan — of course) replacing worn chain links.
G. Does the plant normally operate up to design efficiency for solids removal? (50 - 70%)	SLIDE PR-27 Removal curves for solids.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
H. BOD removal? (35 – 40%)	SLIDE PR-28 Removal curves for BOD
I. Do the clarifiers provide effective scum removal? This one doesn't!	SLIDE PR-29 Scum removal unit.
J. Do you know the normal raw sludge characteristics?	Refer students to Student Notebook table on raw sludge characteristics. Page PR-19.
K. Is the primary process performing as designed in relation to other treatment plant processes? Are the clarifiers performing *their* function as part of the plants overall *waste treatment system*?	Refer students to Notebook list: "Relationships to other Processess." Page PR-19
II. Lab Tests for Process Control and for Troubleshooting (5 Minutes)	
A. "THE PROCESS OF TROUBLESHOOTING – ANALYZE AND LEARN" • Determine data needs • Analyze, sample and test • Process test, modify process and analyze	SLIDE PR-30 (word) Guide: Emphasize steps in the Process of Troubleshooting
B. "LAB TESTS – PRIMARY TREATMENT PROCESS CONTROL AND TROUBLESHOOTING" • Solids settleable and suspended total • BOD • pH • Special tests	SLIDE PR-31 (word)
C. "SPECIAL TESTS USEFUL IN TROUBLESHOOTING PRIMARY TREATMENT" • Jar test for chemical coagulation • Dissolved oxygen • Heavy metals	SLIDE PR-32 (word) Guide: These tests may be needed if special problems exist, i.e., use of chemical coagulants, septicity, etc.
D. Imhoff Cone Test for settelable solids (slide shows unnatural color due to dairy wastes)	SLIDE PR-33 Showing Imhoff Cone
E. Solids Separation – schematic diagram	SLIDE PR-34 Schematic of solids separation

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
III. Troubleshooting Problems in Primary Treatment (30 Minutes)	
A. "PROBLEM ANALYSIS IN PRIMARY TREATMENT" Troubleshooting for Problem • Causes • Alternative corrections • Prevention	SLIDE PR-35 (word)
B. "COMMON PROBLEMS – PRIMARY TREATMENT" • Floating sludge • Septic wastewater • Growths on weirs • Sediment in inlet channels	SLIDE PR-36 (word)
C. "MORE COMMON PROBLEMS – PRIMARY TREATMENT • Surging or intermittent flow • Scraper or shear pin failure • Sludge removal from hopper • Excessive corrosion	SLIDE PR-37 (word)
	Guide: For three of these problems – show slide depicting problem – then lead class discussion on its cause, prevention, and correction. The class should be encouraged to suggest alternative ways of handling problems. You have about 5 minutes for each problem.
D. Floating Sludge (5 Minutes)	Show slides PR-38 and PR-39 which show sludge decomposing and buoyed to the surface.
1. "FLOATING SLUDGE" • Causes? • Alternative corrections? • Prevention	Show Word slide PR-40. Keep slide on screen while discussing this topic. Instructor should *stimulate* class involvement.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
2. Troubleshooting Guide – Floating Sludge	
a. Cause: sludge decomposing in tank and buoyed to surface	Instructor may use troubleshooting guide as a reference in discussing this problem.
b. Prevention: 1. Remove sludge more completely or frequently	
c. Correction: 1. Operate mechanical scrapers for longer periods or continuously 2. Repair or replace broken or warped wooden flights 3. Remove sludge from hoppers more completely by gravity withdrawal or pumping for longer periods or at slower rates 4. Where sludge clings to inclined surfaces, remove by squeegeeing solids to sludge hopper	
E. Septic Wastewater (5 Minutes)	
1. "SEPTIC WASTEWATER – BLACK AND ODOROUS" ● Causes? ● Alternative corrections? ● Prevention?	SLIDE PR-41 (word) Keep on screen during discussion.
2. Troubleshooting guide – Septic Wastewater	Instructor may use troubleshooting guide as a reference in discussing this problem.
a. Cause: flat grades in collection system, improper operation of lift stations, heavy industrial waste, shock loads from commercial haulers, digestor supernatant, or improper solids withdrawal from unit.	
b. Prevention 1. Maintain velocities in collection lines by flushing program. 2. Inspect lift stations daily for proper operation. 3. Industrial plants and commercial haulers should provide pretreatment of strong wastes.	Show Slide PR-42 Floating Septic Sludge in a Primary Clarifiers Following an Overnight Accumulation.

LESSON OUTLINE

4. Digestor supernatant should receive further treatment before entering head of plant.
5. Regular program of withdrawing solids from unit.

c. Correction:

1. Pre-aerate types of wastes listed above
2. Chlorinate in collection system ahead of treatment plant or ahead of sedimentation tank to delay or reduce decomposition of wastewater
3. Improve hydraulics of wastewater system to reduce accumulations of solids
4. Digestor supernate: cure
   a. correct or improve sludge digestion to produce improved quality supernate
   b. Reduce rate of withdrawal of supernatant to sedimentation tank
   c. Pre-settle or elutriate the supernatant
   d. Select better quality of supernatant from another zone or delay withdrawal until quality improves
   e. Discharge a portion or all of supernatant, until quality improves, to other points such as: sludge drying bed or supernatant aeration tank
5. Systematic program of sludge removal from sedimentation unit

F. Broken Scraper chains or shear pin failures (5 Minutes)

KEY POINTS & INSTRUCTOR GUIDE

Show slide PR-43 Covered Primaries in a Warm Climate Where Septic Wastewater is Common. Gas is circulated to aerators to reduce odors.

Show slide PR-44 which shows this problem.

Slide PR-45 – broken scraper. Also note in background that baffles are in need of repair.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
1. "BROKEN SCRAPER CHAINS OR SHEAR PIN FAILURES" • Causes? • Alternative corrections? • Prevention?	SLIDE PR-46 (word) Keep on screen while discussing this topic. Instructor should continue to stimulate class involvement.
2. Troubleshooting guide – Broken Scraper Chains shear pin failures a. Cause: Excessive load on sludge scraper b. Prevention: 1. Periodically dewater tank and examine all metal parts for defects and wear 2. Replace defective and worn parts c. Correction: 1. Operate collector mechanism continuously or for longer periods and/or pump sludge more often 2. Operate grit chamber or reduce entrance of grit to tank if grit accumulation is substantial 3. Remove or break up ice formation on walls and surfaces	Instructor may use Troubleshooting Guide as a reference in discussing this problem.
G. Discussion of Other Primary Treatment Problems (10 Minutes). 1. Briefly review Troubleshooting Guide 2. Portrayal of Other Problems.	Refer students to Student Notebook – Troubleshooting Guide for eight common problems in Primary Treatment – pages PR-20 thru PR-22.
a. Sediment and sludge in inlet channel. Note from slide the scum collector that has been out of use. Sludge cake was 6 in. thick and very difficult to remove.	Slide PR-47
b. Surging flow. Substantial solids overflow due to poor pump programming causing hydraulic and organic overload.	Slide PR-48
c. Sludge removal from hopper. Sectional diagram shows solids buildup. Best corrected by more frequent sludge pumping.	Slide PR-49

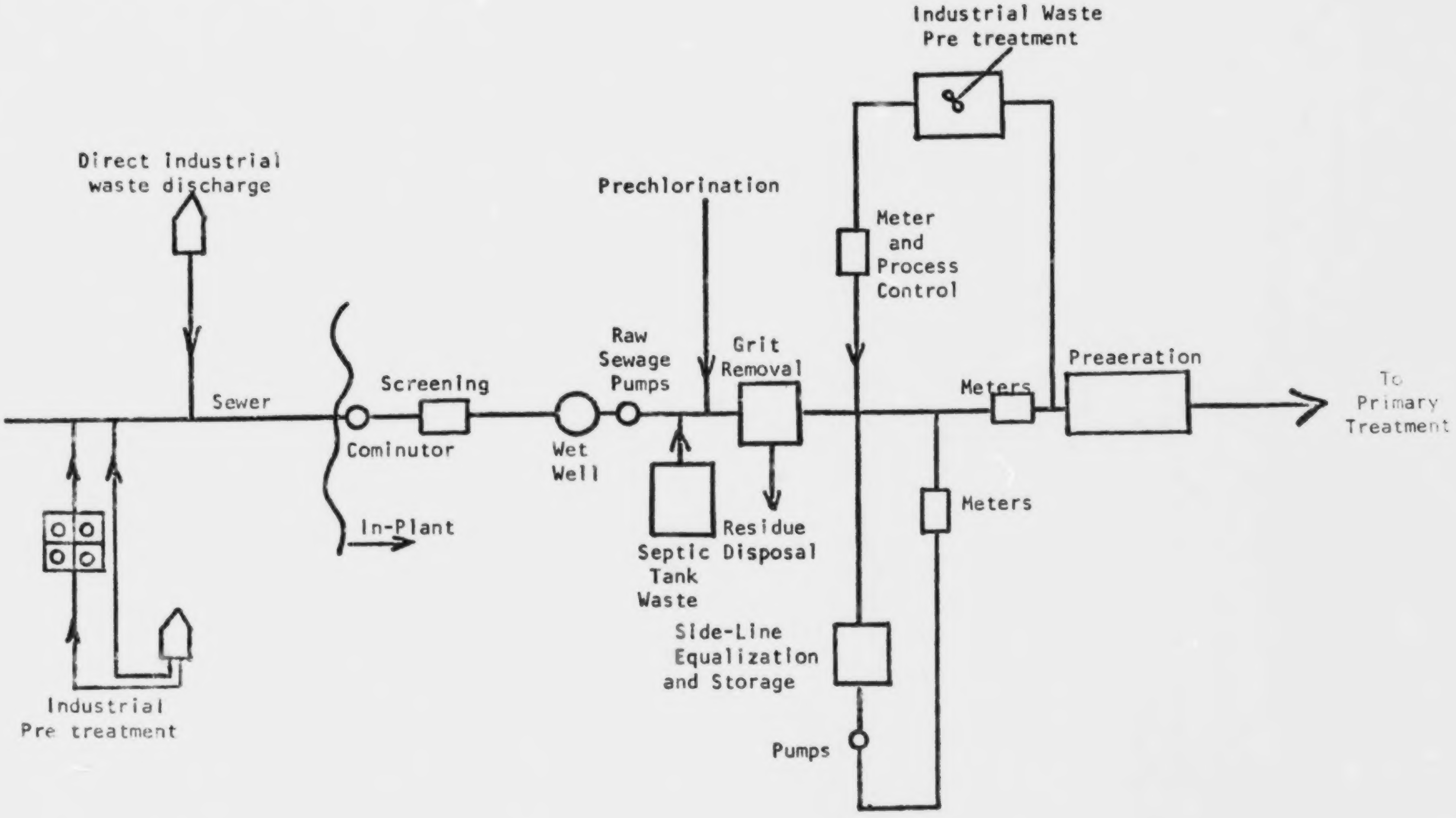
LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
d. Excessive Corrosion. Inoperative scum removal apparatus caused by long term corrosion, improper O & M	Slide PR-50
IV. Summary and Discussion (5 Minutes)	Guide: Instructor should emphasize the important steps of implementing troubleshooting actions, and that in troubleshooting problems in Primary Treatment, there are several types of actions recommended.
A. "TYPES OF TROUBLESHOOTING ACTIONS RECOMMENDED – PRIMARY TREATMENT" • Process and operational changes • Equipment repair • Cleaning and maintenance • Chemical additions	SLIDE PR-51 (word) Refer to troubleshooting chart, line 5a.
B. "TROUBLESHOOTING ACTIONS SHOULD" • Solve immediate breakdown • Prevent recurrence • Improve long run maintenance and prevention of problems • Improve long run efficiency	SLIDE PR-52 (word)
C. "TROUBLESHOOTER'S ACTIONS MUST" • Receive acceptance of operator • Be within financial and manpower capability • Keep plant within design capacity • Solve both short- and long-run problems	SLIDE PR-53 (word) Key Point: Instructor should stress the contents of this slide.
D. "FINAL TROUBLESHOOTING STEPS INCLUDE" • Overseeing implementation • Monitoring results • Documenting results • Follow-up	SLIDE PR-54 (word) Key Point: Stress the troubleshooter's role in follow-up.
E. In any remaining time, instructor should summarize the lesson and call for class questions and discussion.	

STUDENT NOTEBOOK MATERIALS

The following materials are included in the section of the Student Notebook on Pretreatment/Primary Treatment. The Notebook is distributed to students at the start of the course, and is available to them as a reference material throughout the course.

Index of Notebook Materials

Pages	Material	Use in Lesson
PR 1	Schematic Flow diagram of pretreatment process components	Used by instructor Subdivision 1, Section 1
PR 2 PR 3	Plant Information and background Problem Worksheet	For use by student groups in solving problem assigned in Subdivision 1.
PR 4-16	Sample Sewer Use Ordinance	For student reference in relation to Subdivision 1, Section III on Sewer Use Ordinances.
PR 17-18	Flow Diagrams on Flow Equalization taken from "Upgrading Existing Wastewater Treatment Plants" EPA.	For student reference in Subdivision 1, Section IV, Flow Equalization.
PR 19	Table on Raw Sludge Characteristics and Relationship to other Processes	Used by instructor, Subdivision 3, Section I.
PR 20-22	Troubleshooting Guide, Primary Treatment	For Student Reference, Subdivision 3, Section III, on Troubleshooting.
PR 23	References	


Industrial Waste
Pre treatment
Direct industrial
waste discharge
Prechlorination
Meter
and
Process
Control
Raw
Sewage
Pumps
Grit
Removal
Preaeration
Screening
Sewer
Meters
To
Primary
Treatment
Cominutor
Wet
Well
Meters
In-Plant
Residue
Disposal
Septic
Tank
Waste
Side-Line
Equalization
and Storage
Industrial
Pre treatment
Pumps

Schematic Flow Diagram of
Pretreatment Process Components

GROUP ______________________________

TROUBLESHOOTING PROBLEM – PRETREATMENT

PLANT BACKGROUND:

Plant flow is excess of 10.0 MGD

Essential Equipment:

1. Pump station following a 2 inch bar screen
2. Comminutor in alternate channels
3. Pumps and preliminaries in a below grade pit
4. Primary treatment (2) clarifiers
5. Activated sludge surface aerators
6. Final clarifiers (2)
7. Anaerobic digesters

INITIAL OBSERVATION AND ANALYSIS BY TROUBLESHOOTER:

The plant facility has what appears to be adequate capacity but little versatility. Preliminary screen has an open channel behind it with poor facilities for cleaning screens and lifting screening out of the pit (approximately 25 ft down). Flow distribution, measurement, and control devices require real ingenuity and agility to master the situation and to achieve effective plant performance.

OBSERVATIONS ON MANAGEMENT BEHAVIOR:

1. Laboratory facilities and support appear weak
2. The plant is understaffed
3. Comments from staff lead you to believe that they get little support from city hall for their problems
4. Staff appear to be hard working, and trying
5. Records are scant except for the absolute minimum. There is little confidence in the records, except that they accurately show the plant to be not performing up to its design
6. Process controls are limited. The staff is too busy just keeping the wastewater moving and solving problems like the one shown in the slide

GROUP ______________________________ **Problem Worksheet**

TROUBLESHOOTING PROBLEM – PRETREATMENT

Student groups should answer the following questions.

1. What is the location of the problem shown in the slide?

2. What is the nature of the problem?

3. What is the most likely cause of the problem, based upon your knowledge of the plant as a troubleshooter?

4. What corrective actions would you recommend?

5. Do you see additional problems shown in the slide?

You have 10 minutes to complete this worksheet, at which time the problem will be discussed by the class.

SAMPLE
SEWER USE ORDINANCE

ARTICLE I
DEFINITIONS

Unless the context specifically indicates otherwise, the meaning of terms used in this ordinance shall be as follows:

Sec. 1. "Biochemical oxygen demand" (BOD) shall mean the quantity of oxygen utilized in the biochemical oxidation of organic matter under standard laboratory procedure in five (5) days at 20°C, expressed in milligrams per liter.

Sec. 2. "Building drain" shall mean that part of the lowest horizontal piping of a drainage system which receives the discharge from soil, waste, and other drainage pipes inside the walls of the building and conveys it to the building sewer, beginning five (5) feet (1.5 meters) outside the inner face of the inner face of the building wall.

Sec. 3. "Building sewer" shall mean the extension from the building drain to the public sewer or other place of disposal, also called house connection.

Sec. 4. "Chemical oxygen demand" (COD) shall mean the quantity of oxygen utilized in the chemical oxidation of organic matter under standard laboratory procedures expressed in milligrams per liter.

Sec. 5. "Combined sewer" shall mean a sewer intended to receive both wastewater and storm or surface water.

Sec. 6. "Compatible pollutant" shall mean BOD, suspended solids, acceptable pH range, and fecal coliform bacteria, plus additional pollutants identified in the NPDES permit if the publicly owned treatment works was designed to treat such pollutants, and in fact does remove such pollutants to a substantial degree. Examples of such additional pollutants may include: a) COD; b) total organic carbon; c) phosphorus and phosphorus compounds; d) nitrogen and nitrogen compounds; e) fats, oils, and greases of animal or vegetable origin except as prohibited under Article ( ), Sec. 4.

Sec. 7. "Engineer" shall mean the Engineer of the [Village] of ( ) or his authorized representative.

Sec. 8. "Federal Act" shall mean the Federal Water Pollution Control Act Amendments of 1972, Public Law 92-500, and any amendments thereto; as well as any guidelines, limitations, and standards promulgated by the U.S. Environmental Protection Agency pursuant to the Act.

Sec. 9. "Floatable oil" is oil, fat, or grease in a physical state such that it will separate by gravity from wastewater by treatment in an approved pretreatment facility.

Sec. 10. "Garbage" shall mean the animal and vegetable waste resulting from the handling, preparation, cooking, and serving of food.

Sec. 11. "Incompatible pollutant" shall mean any pollutant which is not a compatible pollutant as defined in Sec. 6.

Sec. 12. "Industrial wastes" shall mean the wastewater from industrial processes, trade, or business as distinct from domestic or sanitary wastes.

Sec. 13. "Major contributing industry" shall mean an industrial user of the publicly-owned treatment works that: (a) has a flow of 50,000 gallons or more per average work day; (b) has a flow greater than five (5) percent of the flow carried by the municipal system receiving the waste; (c) has in its waste, a toxic pollutant in toxic amounts as defined in standards issued under Section 307(a) of the Federal Act; or (d) is found by the permit issuance authority in connection with the issuance of an NPDES permit to the publicly owned treatment works receiving the waste, to have significant impact, either singly or in combination with other contributing industries, on that treatment works or upon the quality of effluent from that treatment works.

Sec. 14. "May" is permissive; "Shall" is mandatory.

Sec. 15. "Natural outlet" shall mean any outlet, including storm sewers and combined sewer overflows, into a watercourse, pond, ditch, lake, or other body of surface or groundwater.

Sec. 16. "NPDES" permit shall mean the National Pollutant Discharge Elimination System permit.

Sec. 17. "Person" shall mean any individual, firm, company, association, society, corporation, or group.

Sec. 18. "pH" shall mean the reciprocal of the logarithm of the hydrogen ion concentration. The concentration is the weight of hydrogen ions, in grams, per liter of solution. Pure water, for example, has a pH value of 7 and a hydrogen ion concentration of 10^{-7}

Sec. 19. "Pollutant" shall mean dredged spoil, solid waste, incinerator residue, wastewater, garbage, wastewater sludge, munition, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal, and agricultural waste discharged into water.

Sec. 20. "Properly shredded garbage" shall mean the wastes from the preparation, cooking, and dispensing of food that have been shredded to such a degree that all particles will be carried freely under the flow conditions normally prevailing in public sewers, with no particle greater than 1/2 inch (1.27 centimeters) in any dimension.

Sec. 21. "Pretreatment" shall mean the treatment of wastewaters from sources before introduction into publicly owned wastewater treatment facilities.

Sec. 22. "Public sewer" shall mean a common sewer controlled by a governmental agency or public utility.

Sec. 23. "Sanitary sewer" shall mean a sewer that carries liquid and water-carried wastes from residences, commercial buildings, industrial plants, and institutions together with minor quantities of ground, storm, and surface waters that are not admitted intentionally.

Sec. 24. "Slug" shall mean any discharge of water or wastewater which in concentration of any given constituent or in quantity of flow exceeds for any period of duration longer than fifteen (15) minutes more than five (5) times the average twenty-four (24) hour concentration of flows during normal operation and shall adversely affect the collection system and/or performance of the wastewater treatment works.

Sec. 25. "Storm drain" (sometimes termed "storm sewer") shall mean a drain or sewer for conveying water, groundwater, subsurface water, or inpolluted water from any source.

Sec. 26. "Superintendent" shall mean the [Superintendent of wastewater facilities, and/or of wastewater treatment works, and/or of water pollution control] of the [Village] of [   ], or his authorized deputy, agent, or representative.

Sec. 27. "Suspended solids" shall mean total particulate matter that either floats on the surface of, or is in suspension in, water, wastewater, or other liquids, and that is removable by laboratory filtering as prescribed in "Standard Methods for the Examination of Water and Wastewater" and referred to as nonfilterable residue.

Sec. 28. "Toxic pollutants" shall include but not necessarily be limited to aldrin-dieldrin, benzidine, cadmium, cyanide, DDT-endrin, mercury, polychlorinated biphenyls (PCB's) and toxaphene. Pollutants included as "toxic" shall be those promulgated as such by the United States Environmental Protection Agency.

Sec. 29. "Unpolluted water" is water of quality equal to or better than the effluent criteria in effect or water that would not cause violation of receiving water quality standards and would not be benefited by discharge to the sanitary sewers and wastewater treatment facilities provided.

Sec. 30. "Wastewater" shall mean the spent water of a community. From the standpoint of source, it may be a combination of the liquid and water-carried wastes from residences, commercial buildings, industrial plants, and institutions, together with any groundwater, surface water, and stormwater that may be present.

Sec. 31. "Wastewater facilities" shall mean the structures, equipment, and processes required to collect, carry away, and treat domestic and industrial wastes and dispose of the effluent.

Sec. 32. "Wastewater treatment works" shall mean an arrangement of devices and structures for treating wastewater, industrial wastes, and sludge. Sometimes used as synonymous with "waste treatment plant" or "wastewater treatment plant" or "water pollution control plant."

Included among the definitions of a particular ordinance should be those for such terms as "city," "village" and various officials as are locally applicable.

ARTICLE (   )

Use of Public Sewers

Sec. 1. *Prohibition on Unpolluted Water* – No person shall discharge or cause to be discharged any (unpolluted) stormwater, surface water, groundwater, roof runoff, subsurface drainage, uncontaminated cooling water, or unpolluted industrial process waters to any sanitary sewer. Any existing roof drain connections to sanitary (or combined) sewers shall be connected into an available storm sewer or shall be disconnected above ground in the manner approved by the [Board of Public Affairs]. The owner of all buildings situated within the [Village] is required at his expense to disconnect all existing roof drains from sanitary [and combined] sewers in accordance with the provisions of this chapter within 90 days after the date of official notice to do so.

Sec. 2. *Allowable Discharge of Unpolluted Water* – Stormwater and all other unpolluted drainage shall be discharged to such sewers as are specifically designated as combined sewers or storm drains or to a natural outlet approved by the [Board of Public Affairs] and other regulatory agencies. Unpolluted industrial cooling water or process waters may be discharged on approval by the [Board of Public Affairs] to a storm sewer, or natural outlet.

Sec. 3. *Substances Prohibited* – No person(s) shall discharge or cause to be discharged any of the following described waters or wastes to any public sewers [or treatment works]:

a) Any gasoline, benzene, naptha, fuel oil, or other flammable or explosive liquid, solid, or gas.

b) Any waters or wastes having a pH lower than [6.0] or having any other corrosive property capable of causing damage or hazard to structures, equipment, and personnel of the wastewater works.

c) Solid or viscous substances in quantities or of such size capable of causing obstruction to the flow in sewers or other interferences with the proper operation of the wastewater facilities such as, but not limited to, ashes, bones, cinders, sand, mud, straw, shavings, metal, glass, rags, feathers, tar, plastics, wood, unground garbage, whole blood, paunch manure, hair and fleshings, entrails, and paper dishes, cups, milk containers, etc., either whole or ground by garbage grinders.

Sec. 4. *Substances Limited* – The following described substances, materials, waters, or waste shall be limited in discharges to municipal systems to concentrations or quantities which will not harm either the sewers, wastewater treatment process or equipment, will not have an adverse effect on the receiving stream, or will not otherwise endanger lives, limbs, public property, or constitute a nuisance. The [Superintendent] may set limitations lower than the limitations established in the regulations below if in his opinion such more severe limitations are necessary to meet the above objectives. Deliberate dilution with unpolluted water to meet the concentrations established in the regulations below shall not be acceptable. In forming his opinion as to the acceptability, the [Superintendent] will give consideration to such facts as the quantity of subject waste in relation to flows and velocities in the sewers, materials of construction of the sewers, the wastewater treatment process employed, capacity of the wastewater treatment plant, degree of treatability of the waste in the wastewater treatment plant, and other pertinent factors. The limitations or restrictions on materials or characteristics of waste or wastewater discharged to the sanitary sewer which shall not be violated without approval of the [Superintendent] are as follows:

a) Wastewater having a temperature higher than 150°F

b) Wastewater containing more than 50 milligrams per liter of petroleum oil, nonbiodegradable cutting oils, product of mineral oil origin, or floatable oils, fat, wax, or grease.

c) Any garbage that has not been properly shredded. Garbage grinders may be connected to sanitary sewers from homes, hotels, institutions, restaurants, hospitals, catering establishments or similar places where garbage originates from the preparation of food in kitchens for the purpose of consumption on the premises or when served by caterers.

d) Any waters or wastes containing solids, liquids, or gases in sufficient quantity, either singly or by interaction with other wastes to injure or interfere with any wastewater treatment process, constitute a hazard to humans or animals, create a public nuisance, or create any hazard in the receiving waters of the Wastewater Treatment Plant, including, but not limited to cyanides, hexavalent chromium, copper, zinc, cadmium, nickel and phenols in the wastes as discharged to the public sewer. The following concentrations shall not be exceeded in industrial wastes discharged to the public sewers:

total cyanide (CN), 0.5 milligrams per liter (mg/l)

hexavalent chromium, 1.0 mg/l

copper, 1.0 mg/l

zinc, 1.0 mg/l

cadmium, 0.2 mg/l

nickel, 2.0 mg/l

phenols, 0.2 mg/l

lead, 0.5 mg/l

mercury, 0.01 mg/l

silver, 0.2 mg/l

These maximum concentrations may be changed as necessary by the [Superintendent] or state regulatory agencies based on new information concerning inhibitory substances or to protect treatment plant processes. Industrial discharges covered by Federal pretreatment requirements shall meet those limitations specified under the effluent guidelines published under Sections 304 (b) and 307 (b) of the Federal Act or the above concentrations, whichever is more stringent. Major contributing industries discharging incompatible pollutants into the public sewers shall be regulated as provided in Article [ ], Sec. 5.

e) Any waters of wastes containing odor-producing substances exceeding limits which may be established by the [Superintendent] or any local or state regulatory agencies.

f) Any radioactive wastes or isotopes of such half-life or concentration as may exceed limits in compliance with applicable state or Federal regulations.

g) Quantities of flow, concentrations or both which constitute a "slug" as defined herein.

h) Waters or wastes containing substances which are not amenable to treatment or reduction by the wastewater treatment processes employed, or are amenable only to such degree that the wastewater treatment plant effluent cannot meet the requirements of other agencies having jurisdiction over discharge to the receiving waters.

i) Any water or wastes which by interaction with other water or wastes in the public sewer system, release obnoxious gases, form suspended solids which interfere with the collection system, or create a condition deleterious to structures and treatment processes.

Sec. 5. *Authority for Control of Wastewater Discharges* – If any waters or wastes are discharged or are proposed to be discharged to the public sewers, which contain the substances or possess the characteristics enumerated in [Sec. 3 and/or 4] of this Article, and which in the judgment of the [Engineer], may have a deleterious effect upon the wastewater facilities, processes, equipment, or receiving waters, including violation of applicable water quality standards, or which otherwise create a hazard to life or constitute a public nuisance, the [Engineer] [shall, may]

a) Reject the wastes

b) Require pretreatment to an acceptable condition for discharge to the public sewers

c) Require control over the quantities and rates of discharge, and/or

d) Require payment to cover the added cost of handling and treating the wastes under the provisions of [Article (   )]

All industrial wastes discharged to the public sewers by major contributing industries shall as a minimum meet the national pretreatment standards or best practical control technology currently available for incompatible pollutants as published in Title 40 Code of Federal Regulations Part 128, unless the [Village] is committed, in its NPDES permit, to remove a specified percentage of the incompatible pollutant. In those instances the applicable pretreatment standards may be correspondingly reduced to levels determined by the [Engineer], or his duly authorized representative, or state regulatory agencies.

If the [Engineer] [requires] pretreatment or equalization of waste flows, the design and installation of the plants and equipment shall be subject to the review and approval of the [Engineer] and state regulatory agencies and subject to the requirements of all applicable codes, ordinances, and laws.

Sec. 6. *Grease and Oil Interceptors* – For grease, oil, and inorganic material such as sand, grit, etc., interceptors shall be provided when in the opinion of the [Engineer], they are necessary for the proper handling of liquid wastes containing floatable grease in excessive amounts, as specified in Section 4(b), or any flammable wastes, sand, or other harmful ingredients; except that such interceptors shall not be required for private living quarters or dwelling units. All interceptors shall be of a type and capacity approved by the [Engineer], and shall be located as to be readily and easily accessible for cleaning and inspection. In the maintaining of these interceptors the owner(s) shall be responsible for the proper removal and disposal by appropriate means of the captured material and shall maintain records of the dates, and means of disposal which are subject to review by the [Superintendent]. Any removal and hauling of the collected materials not performed by the owner(s)' personnel must be performed by currently licensed waste disposal firms.

Sec. 7. *Operation of Pretreatment Facilities* – Where pretreatment or flow-equalizing facilities are provided or required for any waters or wastes, they shall be maintained continuously in satisfactory and effective operation by the owner(s) at his expense.

Sec. 8. *Analyses* – All measurements, tests, and analyses of the characteristics of waters and wastes to which reference is made in this ordinance shall be determined in accordance with the latest edition of "Standard Methods for the Examination of Water and Wastewater," published by the American Public Health Association. Sampling methods, location, times, durations, and frequencies are to be determined on an individual basis subject to approval by the [Superintendent].

Sec. 9. *Special Conditions* – No statement contained in this article shall be construed as preventing any special agreement or arrangement between the [Village] and any industrial concern whereby an industrial waste of unusual strength or character may be accepted by the [Village] for treatment, subject to possible payment therefore by the industrial concern for subsequent treatment. Any industrial concern may appeal to the [Board of Control] any determination made by the [Engineer] in the enforcement of this ordinance.

ARTICLE (   )

Control of Industrial Wastes

Sec. 1. *Submission of Basic Data* – Within thirty (30) days after passage of this Ordinance, each person whose operation entails the discharge of industrial wastes to a public sewer shall prepare and file with the [Engineer] a written statement setting forth the nature of the operation contemplated or presently carried on, the amount and source of water required for use, the proposed point of discharge of said wastes into the wastewater collection system of the [Village], the estimated amount to be so discharged and a fair statement setting forth the expected bacterial, physical, chemical, and other known characteristics of said wastes. Within a reasonable time of receipt of such statement, it shall be the duty of the [Village] to make an order stating such minimum restrictions as in the judgment of the [Engineer] may be necessary to adequately guard against unlawful uses of the [Village's] wastewater system.

Sec. 2. *Extension of Time* – When it can be demonstrated that circumstances exist which would create an unreasonable burden on the person to comply with the time schedule imposed by Sec. 1 of this Article, a request for extension of time may be presented for consideration of the [Engineer]. All requests for extension of time shall be submitted in writing stating the reason for such a request. Under no circumstances shall the extension of time exceed thirty (30) days after approval of the extension by the [Engineer].

Sec. 3. *Control Manholes* – Each person discharging industrial wastes into a public sewer shall construct and maintain one or more control manholes or access points to facilitate observation, measurement and sampling of his wastes, including sanitary wastewater.

Control manholes or access facilities shall be located and built in a manner acceptable to the [Engineer]. If measuring devices are to be permanently installed they shall be of a type acceptable to the [Engineer].

Control manholes, access facilities, and related equipment shall be installed by the person discharging the waste at his expense, and shall be maintained by him so as to be in safe condition, accessible and in proper operating condition at all times. Plans for the installation of such facilities shall be approved by the [Engineer] prior to the beginning of construction.

Sec. 4. *Wastewater Volume Determination* – The volume of flow used for computing industrial waste surcharges shall be the metered water consumption of the person as shown in the records of water meter readings maintained by the [Village] except as herein provided in this section.

If the person discharging industrial wastes into the public sewers procures any part, or all, of this water from sources other than the [Village] water system, all or part of which is discharged into the public sewer, the person shall install and maintain at his expense water meters of a type approved by the [Engineer] for the purpose of determining the volume of water obtained from those other sources.

The person discharging industrial wastes into the public sewers may install and maintain at his expense metering devices for determining the volume of waste being discharged to the public sewer, from which the industrial waste surcharge would be computed. The measuring devices shall be of a type acceptable to the [Engineer].

The [Engineer] may require the installation of devices for measuring the volume of waste discharged if these volumes cannot otherwise be determined from the metered water consumption records.

Any metering device for determining the volume of waste discharged to the public sewer shall be installed, owned, and maintained by the person. Following approval and installation, such meters may not be removed without the consent of the [Engineer].

Sec. 5. *Sampling and Monitoring* – Industrial wastes discharged into the public sewers shall be subject to periodic inspection with a determination of character and concentration of said wastes. The determination shall be made as often as may be deemed necessary by the [Engineer] but in no case less than two (2) 24-hour composite samples per month. The owner shall be responsible for the collection and testing of the aforementioned samples.

Samples shall be collected in such a manner as to be representative of the composition of the wastes. The sampling shall be accomplished by the use of automatic sampling equipment capable of collecting composite samples.

Access to sampling locations shall be granted to the [Engineer] or his authorized representative at all times. Every care shall be exercised in the collection of samples to insure their preservation in a state comparable to that at the time the sample was taken.

Sec. 6. *Analyses* – Laboratory procedures used in the examination of industrial wastes shall be those set forth in the latest edition of "Standard Methods." However, alternative methods for certain analyses of industrial wastes may be used subject to mutual agreement between the [Engineer] and the person.

Determination of the character and concentration of the industrial wastes shall be made by the person responsible for the discharge, or his qualified agent as approved by the [Engineer]. The results of the analyses shall be reported to the [Village] on a monthly basis on forms provided by the [Village]. The [Village] shall make its own analyses on the wastes and these determinations shall be binding as a basis for charges, except under circumstances in the following paragraph.

In case the analyses performed by the industry and the [Village] result in substantially different values, an effort shall be made by the industry to collect samples at the same time the [Village] collects its own samples. The results of the analyses on the samples collected by the [Village] and the industry shall be compared using the same testing procedures as outlined in the latest edition of "Standard Methods" and the differences negotiated.

ARTICLE (   )

Revenue Schedule

Included within the Article discussing revenue rates, the following section should be included:

Sec. (   ) All persons discharging industrial wastewater into the public sewers as determined under the provisions of this Ordinance shall be subject to surcharges determined monthly solely on the basis of the following formula:

$$P = [A] \times B.O.D. + [B] \times S.S.$$

P = monthly surcharge.

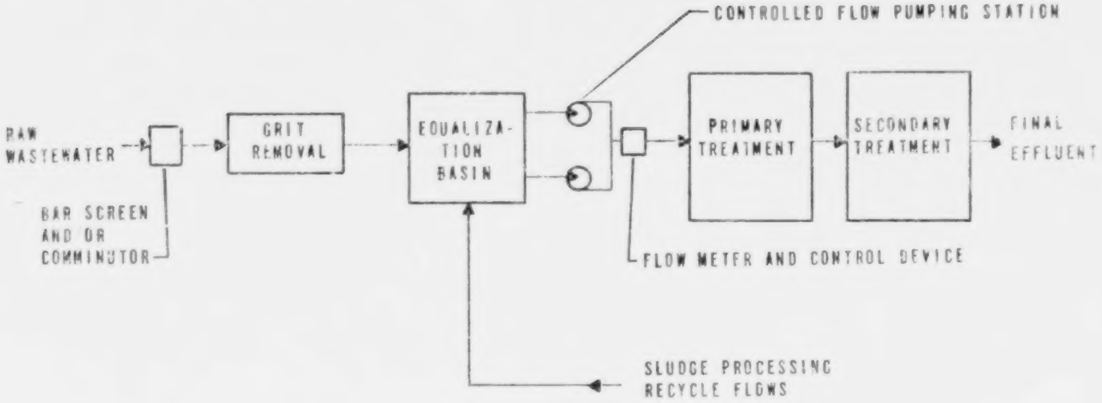
BOD = pounds of biochemical oxygen demand per month in excess of [300] mg/l concentration in the wastewater

SS = pounds of suspended solids per month in excess of [300] mg/l concentration.

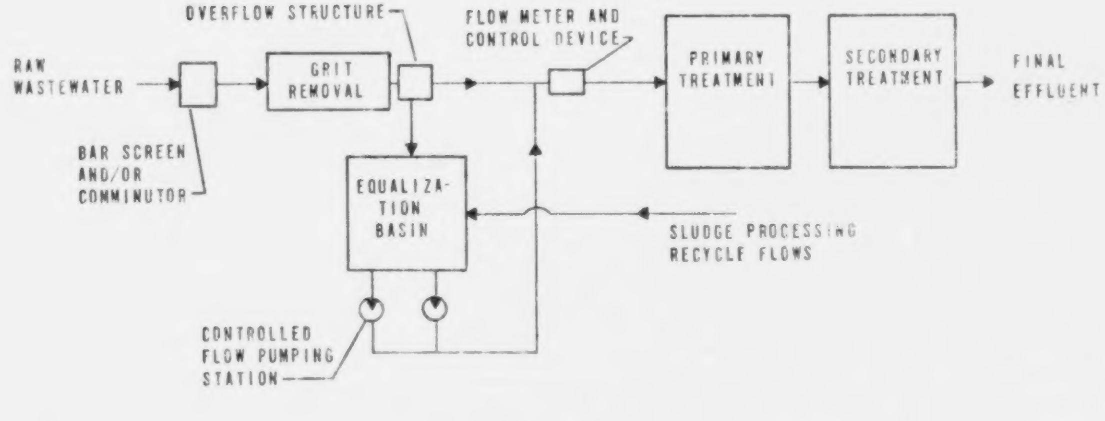
In the above formula A and B refer to the total expenditures per pound of BOD and suspended solids, respectively, to collect, convey and treat the wastewater. This information could be supplied by the Engineer or Superintendent.

Reproduced from EPA "Process Design Manual for Upgrading Existing Wastewater Treatment Plants". Technology Transfer, October, 1974, Chapter 3.

SCHEMATIC FLOW DIAGRAMS OF EQUALIZATION FACILITIES


CONTROLLED FLOW PUMPING STATION
RAW WASTEWATER
GRIT REMOVAL
EQUALIZATION BASIN
PRIMARY TREATMENT
SECONDARY TREATMENT
FINAL EFFLUENT
BAR SCREEN AND OR COMMINUTOR
FLOW METER AND CONTROL DEVICE
SLUDGE PROCESSING RECYCLE FLOWS

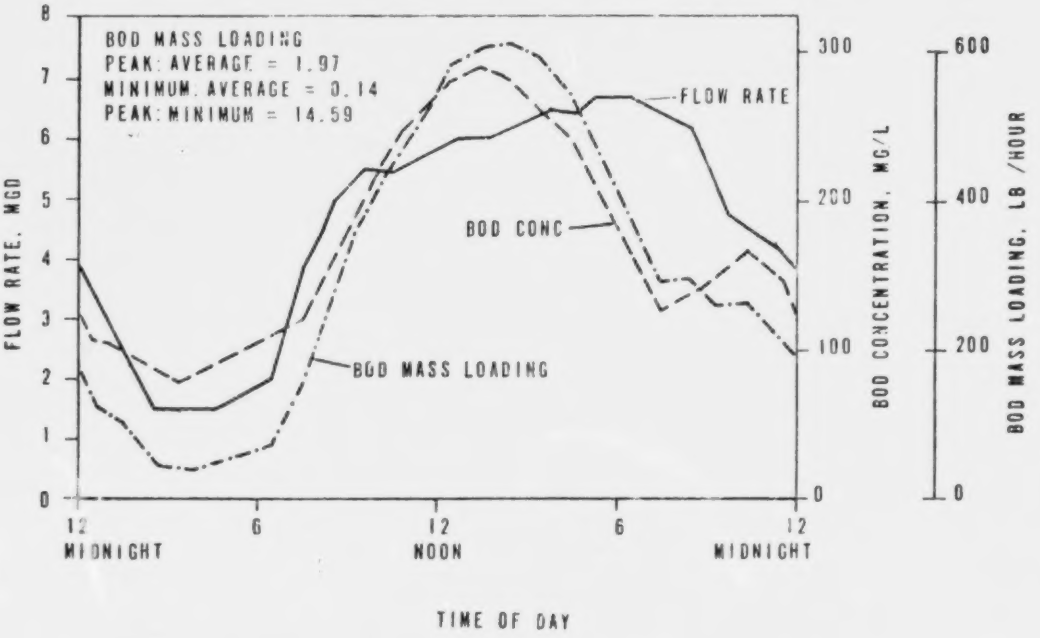
3-1a IN-LINE EQUALIZATION


OVERFLOW STRUCTURE
FLOW METER AND CONTROL DEVICE
RAW WASTEWATER
GRIT REMOVAL
PRIMARY TREATMENT
SECONDARY TREATMENT
FINAL EFFLUENT
BAR SCREEN AND/OR COMMINUTOR
EQUALIZATION BASIN
SLUDGE PROCESSING RECYCLE FLOWS
CONTROLLED FLOW PUMPING STATION

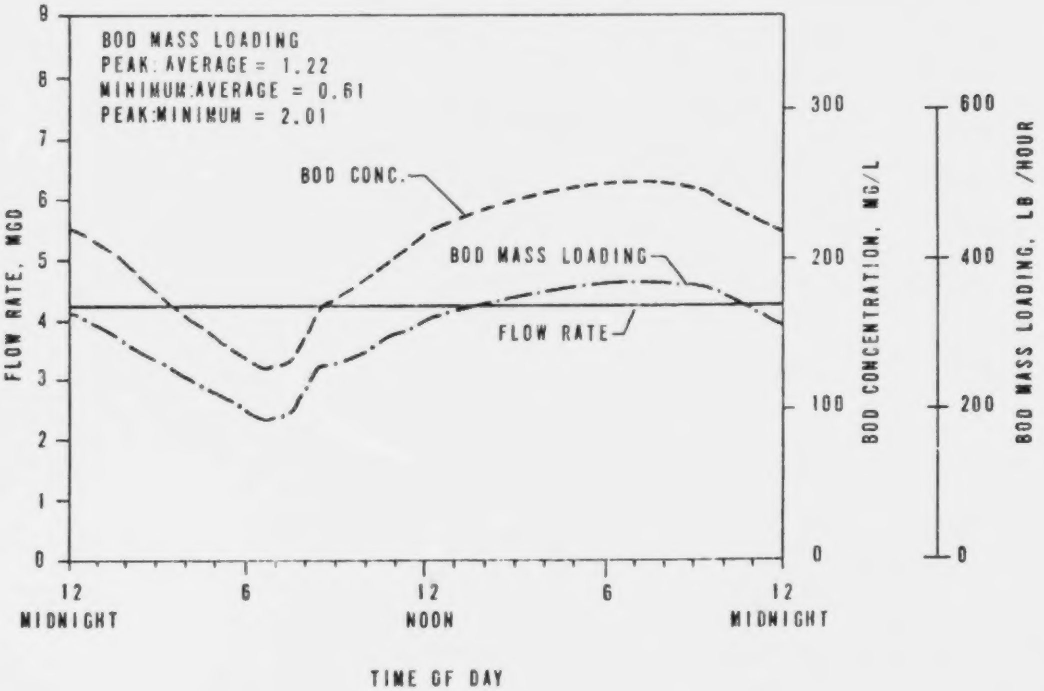
3-1b SIDE-LINE EQUALIZATION

Reproduced from EPA "Process Design Manual for Upgrading Existing Wastewater Treatment Plants". Technology Transfer, October, 1974, Chapter 3.

RAW WASTEWATER FLOW AND BOD VARIATION BEFORE EQUALIZATION



RAW WASTEWATER FLOW AND BOD VARIATION AFTER EQUALIZATION



Information Regarding Normal Operations of a Primary Sedimentation

TABLE 1 – RAW SLUDGE CHARACTERISTICS

1. Physical Texture
   a. Non-uniform
   b. Lumpy
2. Color
   a. Fresh sludge – brownish in color
   b. Septic sludge – dark grey or black
3. Density
   a. Average solids content of 3 – 8%
4. Odor
   a. Normal domestic sludge will have a slight tarry odor
   b. Septic sludge will have an offensive odor
5. Volatile Matter
   a. Average range 70 – 80% of total dry solids
6. pH
   a. Average – 6.0
   b. Range – 5.5 – 6.5
7. Total Alkalinity
   a. Average 650 mg/l
   b. Range 300 – 1,000 mg/l
8. Sludge Volume
   a. Average 250 – 350 ft^3/MG
   b. Range 70 – 700 ft^3/MG
9. Grease Content
   a. Average 15 – 20 mg/l
10. Drainability on Sand Beds
    a. Poor
11. Digestibility
    a. Normally good

RELATIONSHIP OF PRIMARY TREATMENT TO OTHER PROCESSES

1. Will remove 35 – 40% BOD load
2. Will remove 50 – 70% suspended solids
3. Will remove 80 – 99% settleable solids
4. Will remove 90 – 94% grease
5. Will buffer shock load
6. Will increase efficiency of secondary treatment processes

TROUBLESHOOTING GUIDE – PRIMARY TREATMENT

1. Problem: Gassy Floating Sludge

Cause	Prevention	Correction
Sludge decomposing in tank and buoyed to surface	Remove more sludge more completely or frequently	1. Operate mechanical scrapers for longer periods or continuously 2. Repair or replace broken or warped wooden flights 3. Remove sludge from hoppers more completely by gravity withdrawal or pumping for longer periods or at slower rates 4. Where sludge clings to inclined surfaces, remove by squeegeeing solids to sludge hopper

2. Problem: Septic wastewater; black & odorous.

Cause	Prevention	Correction
Flat grades in collection system, improper operation of lift stations, heavy industrial waste, shock loads from commercial haulers, digestor supernatant, or improper solids withdrawal from unit.	1. Maintain correct velocities in collection lines by a flushing program.	1. Pre-aerate wastes.
	2. Inspect lift stations daily for proper operation.	2. Chlorinate in collection system ahead of treatment plant or ahead of sedimentation tank to delay or reduce decomposition of wastewater.
	3. Industrial plants and commercial haulers should provide pretreatment of strong wastes.	3. Improve hydraulics of wastewater system to reduce accumulations of solids.
	4. Digestor supernatant should receive further treatment before entering head of plant.	4. Digestor supernate: cure a. correct or improve sludge digestion to produce improved quality supernate b. reduce rate of withdrawal of supernatant to sedimentation tank c. presettle or elutriate the supernatant d. select better quality of supernatant from another zone or delay withdrawal until quality improves e. discharge a portion or all of supernatant, until quality improves, to other points such as: sludge drying bed or supernatant aeration tank
	5. Regular program of withdrawing solids from unit.	5. Systematic program of sludge removal from sedimentation unit.

3. Problem: Excessive Sedimentation in Inlet Channel

Cause	Prevention	Correction
Velocity too low for cross sectional area of channel at current flow rate	Reduce cross sectional area of channel by installing inner wall of suitable material along one wall of channel	Agitate with air, water or other means to prevent decomposition

4. Problem: Excessive Solids or Growths on Surfaces and Weirs

Cause	Prevention	Correction
Accumulation of wastewater solids and resultant plant growth.	Frequent and thorough scrubbing of all surfaces in contact with wastewater.	Frequent and thorough scrubbing of all surfaces in contact with wastewater.

5. Problem: Intermittent Flow or Surging

Cause	Prevention	Correction
High intermittent pumping rates	1. Adjust pump controls so that larger pumps cut in only at maximum flows 2. Reduce infiltration/inflow in collection system	Install or adjust baffles to reduce inlet velocities and to produce better flow distribution across entire width of tank.

6. Problem: Broken Scraper Chains or Shear Pin Failures

Cause	Prevention	Correction
Excessive load on sludge scraper	1. Periodically dewater tank and examine all metal parts for defects and wear 2. Replace defective and worn parts	1. Operate collector mechanism continuously or for longer periods and/or pump sludge more often 2. Operate grit chamber or reduce entrance of grit tank if grit accumulation is substantial 3. Remove or break up ice formation on walls and surfaces

7. Problem: Sludge Hard to Remove from Hopper

Cause	**Prevention**	**Correction**
1. High content of grit or other easily compacted material. 2. Withdrawal lines with velocity too low or too high.	Reduce grit content by installing grit chamber or locating and correcting sources of grit entering the wastewater system.	1. Loosen compacted material manually or by pressure with air or liquid. 2. Backflush clogged pipelines 3. Pump sludge more frequently 4. Revise sludge piping 5. If piping permits, return digested sludge back to clarifier hopper.

8. Problem: Excessive Corrosion on Unit

Cause	**Prevention**	**Correction**
Septic wastewater or excessive amount of corrosive wastewater gases.	1. Keep all surfaces which come in contact with corrosive wastewater or gases coated with a quality paint (lead paint should not be used where contact with hydrogen sulfide gas may be encountered). 2. Regular preventive maintenance. 3. Proper operation and maintenance of this unit. 4. Install sacrificial anodic protection.	Replace worn out and damaged equipment where appropriate.

REFERENCES – PRETREATMENT – PRIMARY TREATMENT

Federal Guidelines Pretreatment of Pollutants Introduced Into Publicly Owned Treatment Works. US Environmental Protection Agency, Office of Water Program Operations, October 1973. p 167.

Process Design Manual for Upgrading Existing Wastewater Treatment Plants. US Environmental Protection Agency, Technology Transfer, October 1974. p 386.

URS Research Company, Environmental Systems Division. Procedures for Evaluating Performance of Wastewater Treatment Plants. USEPA. San Mateo, California, 1972. p 22.

New England Interstate Water Pollution Control Commission. Controlling the Effects of Industrial Wastes on Sewage Treatment. Prepared by Wesleyan University. 1970.

New York State Department of Health. Manual of Instruction for Sewage Treatment Plant Operators.

Texas Water Utilities Association. Manual of Wastewater Operations. Austin, Texas, 1971

Sacramento State College Department of Civil Engineering. Operation of Wastewater Treatment Plants. Sacramento, California, 1970.

Sub-Committee on Operation of Wastewater Treatment Plants. Operation of Wastewater Treatment Plants, Manual of Practice, No. 11, Washington, D.C., 1970. p 195.

LESSON – TRICKLING FILTERS

Instructor Overview of Lesson

Entry Level Behavior: Students will have had University training in Sanitary Engineering, waste treatment and/or related sciences or equivalent in experience and training. Some field experience in inspecting trickling filters, but none in operating waste treatment facilities.

As a prerequisite to this course, it is recommended that the student will be able to –

1. Identify treatment plant process units.
2. Describe treatment plant process units and equipment in technical terms.
3. Identify and explain the purpose of components of treatment plant process units, how they work and why they are important to the overall process.
4. Describe the normal operating procedures for treatment plant process unit components.
5. Identify when treatment plant process units are not operating properly.

Instructor Objectives: The principal instructor objectives for this lesson are:

1. To present the elements of troubleshooting operational problems at trickling filter plants.
2. To stress the use of the Process of Troubleshooting.
3. To provide realistic problems in the operation of trickling filters for student groups to analyze and solve.
4. To stimulate class discussion on the approach and answers to student problems on trickling filters.

References: Note list of references included with student notebook materials.

Total Length of Lesson: 3 Subdivisions, 2 Hours.

LESSON OVERVIEW

Subdivision Title & Time	Major Student Objectives	Key Points & Content	Approach	Materials
1. Troubleshooting Problems in Trickling Filters	1. Describe trickling filter factors and performance.	1. Basic properties and expected performance of trickling filters.	1. Follow lesson outline	1. Slide series and key
	2. Identify appropriate steps in the Process of Troubleshooting.	2. Importance of trouble-shooter behavior.	2. Rely upon slide series and slide key.	2. Process of Troubleshooting Chart
30 Minutes	3. Identify things to observe, records to review and process control tests for troubleshooting.	3. Importance of daily log, observations and records.		3. EPA Manual "Evaluating the Performance . . . . ." pp 72-76.
	4. List common operating problems and their causes.	4. Importance of testing.		4. Student Notebook, flow diagrams.
	5. Recognize problems in small plants.	5. Special problems in dealing with small plants.		
2. Applying the Process of Troubleshooting	1. Follow systematic approach to solving trickling filter problems.	1. Four operational problems for student groups to identify and develop solutions.	1. Students work in groups.	1. Answer sheet for trickling filter problems in Student Notebook.
45 Minutes	2. Identify problems and their causes.		2. Instructor presents problems with a brief description and slides.	2. Slides to portray trickling filter problems.
	3. List effects and symptoms of trickling filter problems.		3. Groups, through discussion, have 10 minutes to solve each problem as to identity, cause, effects, proposed correction.	3. Slide key – problem guides for the instructor.
	4. Determine methods of correction for operating problems.			

LESSON OVERVIEW (Continued)

Subdivision Title & Time	Major Student Objectives	Key Points & Content	Approach	Materials
3. Problem Reporting and Analysis	1. Compare approaches to solving trickling filter problems.	1. Approach to ventilating trickling filters.	1. Group leaders present approaches to problems.	1. Answer sheets from Subdivision 2.
45 Minutes	2. Evaluate problem approaches to the instructor's suggested solutions.	2. Troubleshooting small plants with part-time operators.	2. Repeat slides depicting problems.	2. Slides from Subdivision 2.
	3. Consider the merits of alternative approaches to trickling filter problems.	3. Maintaining good distribution over filters.	3. Instructor stimulates discussion on groups' approaches.	
		4. Correcting ponding problems.		

LESSON – TRICKLING FILTERS

Presentation Options for Course Director

The two (2) hour lesson on TRICKLING FILTERS is an important part of the overall course material on troubleshooting. Two hours is felt to be appropriate in relation to a total course effort of between 28 and 40 hours. It would be difficult to reduce this lesson below 2 hours and still maintain its continuity. Likewise, it is not recommended that the lesson be expanded, unless there is a particular need to emphasize trickling filters. Therefore, any options for modifying the lesson should be carefully considered by the Course Director. Subjects covered which could be expanded include:

Subdivision 1 – Troubleshooting Problems in Trickling Filters: Where additional detail is desired, this subdivision could be lengthened to 60 or 90 minutes. If it is extended beyond 60 minutes, it is suggested that slides showing trickling filter problems be obtained and used. Also, detailed diagrams of trickling filter construction and operation should be used if the students do not have a basic familiarity with trickling filters.

Subdivision 2 – Applying the Process of Troubleshooting: This subdivision could be extended to 1 hour or more by allowing 5 or more additional minutes to each problem presented to the class.

Subdivision 3 – Problem Reporting and Analysis: This subdivision should remain at 45 minutes. If extended, each group should be asked to present their approach to *each* problem.

TRICKLING FILTERS

Lesson Plan – Subdivision 1 **Time: 30 Minutes**

Title: Troubleshooting Problems in Trickling Filters

Instructor Objectives: To present the elements of troubleshooting operational problems at trickling filter plants. To stress the use of the Process of Troubleshooting as a tool to improve trickling filter performance.

Student Objectives: As a result of this lesson subdivision, students will be able to do the following:

1. List and describe the factors affecting trickling filter performance.
2. Describe the expected performance of trickling filters.
3. Identify the steps in the Process of Troubleshooting used to solve problems in trickling filters.
4. Recognize and employ the important human characteristics of troubleshooter behavior.
5. List things to look for and observe while inspecting trickling filter plants.
6. Identify common deficiencies to observe in trickling filters.
7. List records to be reviewed at trickling filter plants, and recognize the value of different types of plant records.
8. Identify process control tests to run in trickling filters.
9. List and explain tests to be performed while troubleshooting trickling filter plants.
10. List and identify common operating problems in trickling filters.
11. Identify causes of common operating problems.
12. Recognize and describe common problems in small plants.
13. List methods for upgrading trickling filter plants.

Training Materials:

Slide series of 20 word slides, and key Process of Troubleshooting Chart

EPA Manual "Evaluating the Performance of Wastewater Treatment Plants," pages 72-76.

Classroom Set-up:

A normal classroom set-up will be required. Students should be seated with their student groups.

35 mm carousel slide projector with remote controls

Large Screen (8 ft x 10 ft)

Chalkboard or easel

Pointer

Subdivision Schedule:

Within the 30 minute time period, the following schedule should be observed in presenting the lesson plan outline.

Time	Subject
0 – 5 Minutes	Characteristics of trickling filters
5 – 20 Minutes	Troubleshooting Trickling Filter Operations
20 – 30 Minutes	Operational problems.

Subdivision Approach:

The instructor is to rely upon the lesson outline, and particularly upon the slide series and slide key. Student input and discussion is to be encouraged and stimulated by the instructor.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
I. Characteristics of Trickling Filters (5 Minutes)	Key Point: Most field inspectors know and understand trickling filters. To troubleshoot, they must be aware of the basic properties and expected performance of trickling filters.
A. "FACTORS AFFECTING TRICKLING FILTER PERFORMANCE" • Climate • Character of wastes • Distribution over media • Ventilation • Condition of media • Proper underdraining	SLIDE TF-1 (word) Guide: Use this slide to point out the basic information which troubleshooters need to have in approaching a trickling filter problem.
B. "EXPECTED PERFORMANCE – TRICKLING FILTERS" Good Operation→Good Performance • Low rate filters a. 20 to 50 mg/l SS b. 20 to 40 mg/l BOD • High rate filters – same removal with 4 to 6 times the organic loading	SLIDE TF-2 (word) Guide: Troubleshooters should know what to expect from the plants they visit.
C. For typical operating data, refer students to EPA Manual, "Evaluating the Performance of Wastewater Treatment Plants" page 21	Student Notebook page TF-1 shows common flow diagrams for high rate trickling filters.
II. Troubleshooting Trickling Filter Operations (15 Minutes)	
A. "BEGINNING THE PROCESS OF TROUBLESHOOTING" • Visit plant – meet and listen • Observe • Review records • Sample, test, and analyze	SLIDE TF-3 (word) Guide: Use this slide and subsequent slides to review the elements of the Process of Troubleshooting – Step 1 – Analyze and Learn – as applied to trickling filter problems. Refer to Process of Troubleshooting Chart.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
B. “IMPORTANT ELEMENTS OF TROUBLESHOOTING” • Personal contact with operator and staff • Tour plant *with* operator • Concern for operator's problems • Understanding *his* difficulties • Obtaining the operator's point of view and opinion • Listening!	SLIDE TF-4 (word) Key Point: Stress the importance of troubleshooter behavior and the human element in troubleshooting.
C. “OBSERVATIONS – THINGS TO LOOK FOR WHILE TROUBLESHOOTING TRICKLING FILTERS”	SLIDE TF-5 (word) Guide: Have class suggest things that troubleshooters should observe – Then go to next slide which lists such observations to be made.
D. “OBSERVATIONS – TRICKLING FILTERS” • Condition of plant grounds • Color of media – dark green? • Do arms move at uniform rate? • Condition of receiving stream • Maintenance and physical condition of filters • Use of safety precautions	SLIDE TF-6 (word) Common physical deficiencies should be looked for as well – as shown in slide.
E. “TRICKLING FILTERS – COMMON DEFICIENCIES TO OBSERVE” • Solids and grease in effluent • Seal leakage • Clogged nozzles • Splash plate adjustment	SLIDE TF-7 (word)
F. “RECORDS TO REVIEW” • Flow records • Daily log, problems and maintenance • Test results – process controls • Test results – effluent • Pretreatment and industrial controls	SLIDE TF-8 (word) Guide: Show this slide briefly to introduce the next 5 slides which go into records in more detail.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
G. "IMPORTANCE OF FLOW RECORDS" • Are filters being loaded equally? • Do flow meters function properly? • When were meters calibrated? • Can the troubleshooter suggest improvements?	SLIDE TF-9 (word) Guide: Point out to the class that there is a separate lesson on troubleshooting flow measurement problems.
H. "USE THE DAILY LOG!" • Are maintenance activities recorded? Do they yield useful information? • What problems have occurred? • Has weather been a factor? • Are they being honest?	SLIDE TF-10 (word) Key Point: Students with field experience probably can verify the importance of a daily log.
I. "PROCESS CONTROL TESTS RESULTS" • Review lab methods • Are the most useful tests being run? • Are they fudging the results? • Develop honest communication with the operator	SLIDE TF-11 (word)
J. "EFFLUENT TEST RESULTS" • Are NPDES requirements being met? • If not, why? • Can the plant, if well operated, meet requirements? • Do they know why the plant is performing poorly?	SLIDE TF-12 (word)
K. "PRETREATMENT AND INDUSTRIAL CONTROLS" • Do they exist? • Do they effectively enhance the trickling filter operation? • Review with operator – an alert troubleshooter can assist.	SLIDE TF-13 (word)
L. "SAMPLE AND TEST" • Minimum Requirements for Process Control 1. BOD – Daily 2. Suspended Solids – Daily Optional: COD	SLIDE TF-14 (word)

LESSON OUTLINE

M. "USEFUL TESTING FOR TROUBLESHOOTING TRICKLING FILTERS"
- Temperature (icing problems)
- Flow and recirculation rates
- Sulfides (odor problems)
- Size and uniformity of media
- Growths, larvae and snails
- Organic load on filter

III. Operational Problems (10 Minutes)

A. Use of EPA Manual

EPA Manual, "Evaluating the Performance of Wastewater Treatment Plants" has an excellent section on troubleshooting trickling filter problems – pages 72-76.

B. "COMMON TRICKLING FILTER PROBLEMS"
- Ponding
- Odors
- Filter flies
- Icing
- Uneven distribution
- Industrial shockloads
- Heavy sloughing of growth

C. Most likely causes of trickling filter problems.

1. Ponding – overloaded filters and clogged media.
2. Odors – organic overload and anaerobic conditions upstream.
3. Filter flies – often found in low rate filters. Caused by alternating wet and dry environment.
4. Icing – uneven distribution during freezing weather.
5. Uneven distribution – malfunction in waste distribution system, including nozzle clogging, seal leaks or poor spray pattern.
6. Industrial shock loads – no pretreatment ordinance, no flow equalization or pretreatment capability in plant.
7. Heavy Sloughing – changes in loadings or operations.

KEY POINTS & INSTRUCTOR GUIDE

SLIDE TF-15 (word)

Key Point: Knowing what to look for, and what to test, is an important part of identifying and correcting trickling filter operational problems – as presented in the following section.

Refer to EPA Manual "Evaluating . . . . ."

Guide: Because of the EPA Manual – little classtime needs to be spent identifying trickling filter problems.

SLIDE TF-16 (Word)

Guide: Ask class to verbally identify the causes of each of these problems. The causes are listed below for the instructor's reference.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
D. One additional problem should be noted, poor operations due to part-time supervision in small plants.	Key Point: Small plants often have problems all their own, require patience and understanding of the situation.
"SMALL PLANT PROBLEMS" • Part time, busy operators • Low priority of operators • Fiscal constraints • Physical constraints of plant • Fluctuating loads • Seldom have adequate reporting.	SLIDE TF-17 (word)
"HOW TO HELP SMALL PLANTS" • Encourage and assist operator • Communicate with operator on *his* level • Help operator get $ from community • Seek plant flexibility if possible • Simplify reporting	SLIDE TF-18 (word) Guide: The instructor should briefly expand on all of the points shown in this slide.
E. Trickling Filter Upgrading 1. Field inspectors and troubleshooters should be aware of upgrading possibilities, even though it may be beyond their degree of responsibility.	Refer class to Chapter 4, EPA Manual "Upgrading Existing Wastewater Treatment Plants" Refer class to diagrams from that manual reproduced in Student Notebook, pages TF-2 thru TF-5
"TRICKLING FILTER UPGRADING" • Can increase capacity • Can improve waste removal • Is often too major and expensive for troubleshooters to recommend	SLIDE TF-19 (word)
"UPGRADING CAN OCCUR THROUGH" • Improving distribution • Improving recirculation • Adding filters, clarifiers or aeration tanks • Changing media (to plastic) • Chemical additions	SLIDE TF-20 (word) Guide: Note that there is a separate lesson on chemical additions.

TRICKLING FILTERS

Lesson Plan – Subdivision 2 **Time: 45 Minutes**

Title: Applying the Process of Troubleshooting

Instructor Objectives: To provide realistic problems in the operation of trickling filters for student groups to analyze and solve by applying the elements of the Process of Troubleshooting in a group setting.

Student Objectives: As a result of this lesson subdivision, students will be able to do the following:

1. Follow a systematic approach to the solving of operational problems in trickling filters by applying the elements of the Process of Troubleshooting.
2. Identify common trickling filter operational problems.
3. Determine the likely causes of operating problems in trickling filters.
4. List the expected effects and symptoms of each trickling filter operating problem identified.
5. Determine proposed methods of correction for trickling filter operating problems.

Training Materials:

Each student has an answer sheet for trickling filter problems in the student notebook section on trickling filters, therefore, each group of four students will have answer sheets for each of the four problems presented in this subdivision.

Slides, used in sequence, to portray trickling filter problems to the class.

Instructor's lesson plans contain slide key – problem guides for use in presenting problems to the class.

Classroom Set-up:

A normal classroom set-up will be required. Students *must* be seated with their student groups.

35 mm carousel slide projector with remote controls

large screen (8 ft x 10 ft)

Chalkboard or easel

Pointer

Subdivision Schedule:

Within the 45 minute time period, the following schedule should be observed in presenting the lesson plan outline.

Time	Subject
0 – 5 Minutes	Introduce problem session to class
5 – 15 Minutes	Problem 1 – Odor Problem
15 – 25 Minutes	Problem 2 – Maintenance Problem
25 – 35 Minutes	Problem 3 – Poor Distribution
35 – 45 Minutes	Problem 4 – Ponding Problem

Subdivision Approach:

The instructor presents four (4) trickling filter operational problems to the students, as follows:

1. For this subdivision the students should be seated in 4-person groups previously selected by the course director.
2. Each group should have 4 answer sheets for the trickling filter problems. Answer sheets are found in Student Notebook, page TF-6.
3. Each group should designate one (1) person as discussion leader for Problem 1, a second person for Problem 2, etc.
4. Each problem is allotted approximately 10 minutes, as follows:
   2 minutes – presentation by instructor using slides
   8 minutes – analyses by student groups.
5. For each problem, the instructor is to show designated slides, according to the lesson plan outline, from which the students are to identify the problem. In addition, some supplementary information is provided by the instructor. The last slide for each problem is to remain "on" while student groups analyze the problems.
6. The instructor may choose to answer questions, or may decline. If a question is answered for one group, the same information is to be provided to all groups.
7. Student participation and discussion within each group should be encouraged. This lesson subdivision is to be enjoyable as well as instructive to the students.
8. Each group, led by the discussion leader, is to jointly analyze the problem and provide the following on the answer sheet:
   a. statement of problem
   b. likely causes
   c. expected effects and symptoms
   d. proposed methods of correction
9. After 10 minutes, instructor must go to next problem. Class is to be advised in advance that they have 10 minutes for each problem.
10. Following this subdivision, there will be another 45 minute subdivision to discuss and analyze these problems in group discussion.

LESSON OUTLINE

I. Introduction to Problem Analysis (5 Minutes)

- A. Make sure students are seated with their groups, and have answer sheets available to them. (Notebook Page TF-6)
- B. Briefly review the instructions for this subdivision.
- C. Stress that you are looking for the students to use the elements of the Process of Troubleshooting in their systematic approach to solving these problems.
- D. Stress that student participation and involvement is sought.

II. Problem 1 (10 Minutes)

- A. Problem Statement – read to class

  You are dispatched to a trickling filter plant where there has been complaints of odors (we have no sample odors here for you to observe).

  You inspect the incoming sewer system, and the flows are not septic.

  The filter surface looks like this, while the filter media looks like this.

  Keep this slide "on".
- B. Problem Solving Exercise

  Instruct the class to use their answer sheets, and by group discussion identify
  1. the likely causes
  2. expected effects and symptoms
  3. proposed methods of correction
- C. Answers to questions if asked:
  1. It is not summer and there has not been a spell of hot weather.
  2. type of filter – high rate
  3. capacity of plant – 0.8 mgd
  4. Inflow BOD – 200 mg/l
  5. Recirculation ratio – 1:1
- D. Remind students there are 10 minutes for this problem.

KEY POINTS & INSTRUCTOR GUIDE

Guide: Groups are to be predesignated by the course director. Each group should be a balanced cross section of the course's students.

Guide: 2 minutes

Show the following slides.

SLIDE TF-21
SLIDE TF-22

Guide: 8 Minutes

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
III. Problem 2 (10 Minutes)	Note to instructor: This problem is not one of a technical deficiency, but is an exaggerated example of overall lack of operation and maintenance at a small trickling filter plant.
A. Problem Statement – read to class	Guide: 2 minutes
You are on a routine inspection trip and as you drive past the discharge point of a small trickling filter plant you notice the "not so quaint" aroma of untreated sewage. Therefore you drive up to the plant, which you find to be unattended.	Show the following slides –
The filter looks like this, and up close you see this, this, and this. Keep this slide "on".	SLIDE TF-23 SLIDE TF-24 SLIDE TF-25 SLIDE TF-26
B. Problem Solving Exercise	Guide: 8 minutes
Instruct the class to use their answer sheets, and by group discussion identify 1. the likely causes 2. expected effects and symptoms 3. proposed methods of correction	
C. Answers to questions, if asked 1. Plant is operated at a state prison with 783 inmates and 132 staff. 2. It is currently in the middle of the license plate making season.	
D. Remind students, there is a total of 10 minutes for this problem.	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
IV. Problem 3 (10 Minutes)	
A. Problem Statement – read to class	Guide: 2 minutes
Permit monitoring reports submitted to your office for the Obetz city trickling filter plant show a recent loss in removal efficiency with significant increases in BOD and suspended solids in the final effluent.	
As you arrive at the plant,	Show the following slides –
One of the trickling filters looks like this	SLIDE TF-27
while the other looks like this.	SLIDE TF-28
Keep this slide "on."	
B. Problem Solving Exercise	Guide: 8 Minutes
Instruct the class to use their answer sheets, and by group discussion identify	
1. the likely causes 2. expected effects and symptoms 3. proposed methods of correction	
C. Answers to questions if asked:	
1. Obetz has a population of 6,000 people, a small, seasonal vegetable cannery, and three chicken farms.	
2. There have been periodic breakdowns of the primary and pretreatment systems, resulting in poor grease removal and periodic instances of high influent solids.	
D. Remind students there are 10 minutes for this problem.	
V. Problem 4 (10 Minutes)	
A. Problem statement – read to class	Guide: 2 Minutes
As you approach a trickling filter plant on a routine inspection you make a mental note that this should be an easy day, because the plant is usually well run. As you inspect the filters you see:	Show the following slides
this, and in some spots	SLIDE TF-29
this.	SLIDE TF-30
Keep this slide "on".	

LESSON OUTLINE

B. Problem Solving Exercise

Instruct the class to use their answer sheets, and by group discussion identify

1. the likely causes
2. expected effects and symptoms
3. proposed methods of correction

C. Answers to questions if asked –

1. There has been no heavy rain lately.
2. Each filter – there are 2 – has a surface area of 2,000 sq ft
3. The plant is loaded at a rate of 2 mgd

D. Remind the students there are 10 minutes for this problem.

KEY POINTS & INSTRUCTOR GUIDE

Guide: 8 Minutes

ANSWER SHEET

Troubleshooting Problem – Trickling Filters

GROUP NUMBER_______ DISCUSSION LEADER _______________

PROBLEM NUMBER _______________

A. STATEMENT OF PROBLEM

B. LIKELY CAUSES

C. EXPECTED EFFECTS AND SYMPTOMS

D. PROPOSED METHODS OF CORRECTION

Note to Instructor: This is an example of the student answer sheet used for this subdivision. It is found in the Student Notebook, page TF-6.

TRICKLING FILTERS

Lesson Plan – Subdivision 3 **Time: 45 Minutes**

Title: Problem Reporting and Analysis

Instructor Objectives: To stimulate discussion between student groups and among all members of the class on the approach to the problems on trickling filters presented in lesson subdivision 2. To provide students with specific answers to the four problems presented in subdivision 2. To reinforce the relevance of the elements of the Process of Troubleshooting in solving trickling filter operational problems.

Student Objectives: As a result of this lesson subdivision, students will be able to do the following:

1. Compare the approach of their groups to the trickling filter problems presented to the approaches presented by other groups.
2. Evaluate their responses to trickling filter problems in comparison to the instructor's suggested solutions.
3. Consider the merits of alternative approaches to troubleshooting problems in the operation of trickling filters.

Additionally, students will have the opportunity to present their approaches for review by the remainder of the class, and to substantiate their approach by arguing its merits. This lesson subdivision provides the students with the opportunity to receive feedback on their problem approaches.

Training Materials:

Answer Sheets used in lesson subdivision 2. Slides presented in subdivision 2 are to be re-shown during subdivision 3.

Classroom Set-Up:

A normal classroom set-up will be required. Students *must* be seated with their student groups.

35 mm carousel slide projector with remote controls

large screen (8 ft x 10 ft)

chalkboard or easel

pointer

Subdivision Schedule:

Within the 45 minute time period, the following schedule should be observed in presenting the lesson plan outline.

TIME	ACTIVITY
0 – 10 Minutes	Reporting and Analyses of Problem 1
10 – 20 Minutes	Reporting and Analyses of Problem 2
20 – 30 Minutes	Reporting and Analyses of Problem 3
30 – 40 Minutes	Reporting and Analyses of Problem 4
40 – 45 Minutes	Lesson Summary and Conclusions

Subdivision Approach:

1. Students should remain in the student groups used in subdivision 2.
2. Each group selected a discussion leader for each of the problems presented in subdivision 2. The instructor should call on one discussion leader for each problem to report his group's findings. Have other discussion leaders for that problem make additions.
3. While discussing each problem, repeat the slides which accompanied the problem as presented in subdivision 2.
4. If a problem is not completely analyzed by the class, use materials provided in the lesson plan outline to supplement the discussion.
5. The instructor should serve as a discussion catalyst for this subdivision. He should minimize his own role and maximize student participation.
6. After 10 minutes, move on to the next problem.
7. After 40 minutes, sum up the lesson on Trickling Filters.

LESSON OUTLINE

I. Troubleshooting Guide to Problem 1. (10 Minutes)

A. Identity of Problem
As stated, this was an odor problem.

B. Likely Causes.

1. Since the plant inflows are not septic, the most likely cause is inadequate ventilation within the filter.

   This would be caused if air and water temperatures are equal and no thermal exchange takes place.

2. During hot weather, odors may develop from a filter in good operating condition.

C. Effect and symptoms of Problem

1. Black slimes are likely to develop on the media surface.
2. Hydrogen sulfide odors develop in the vicinity of the filters.
3. Nitrification is not occurring – no breakdown: NH_3 → Nitrite → Nitrite

D. Proposed Methods of Correction

1. Maintain aerobic conditions in and properly operate sewer system and settling tanks.
2. Examine underdrain system and ventilation facilities; stoppages in either of these will cut down natural flow of air; natural ventilation occurs if vents are open and difference in air and water temperature is greater than 3° F.
3. Increase recirculation rate to provide more oxygen and to increase sloughing of surface slime.
4. Practice good housekeeping around filter; keep slime growths, resulting from wastewater splashing, off sidewalks and other surfaces.
5. In extreme cases it may be necessary to provide forced air ventilation.

KEY POINTS & INSTRUCTOR GUIDE

Show Slides TF-21, TF-22

Guide: If necessary the instructor should challenge the students into stating how these measures can be implemented.

LESSON OUTLINE

II. Troubleshooting Guide to Problem 2 (10 Minutes)

A. Identity of Problem

This is an exaggerated case where the filter is not being operated and maintained.

B. Likely Causes

1. Little appreciation of the need to treat sewage by the operating agency - the state prison.
2. Diversion of manpower from plant operation to manufacturing.
3. Plant may have been damaged by toxic influents – plating wastes from the license plat manufacturing process.

C. Effects and Symptoms of Problem

1. Untreated sewage is being discharged into the receiving stream.
2. Plant may be seriously damaged and in disrepair.

D. Proposed Methods of Correction

1. Understand the nature of the operator's difficulties – part time responsibilities, fiscal constraints, etc.
2. Offer to provide assistance and guidance to the operating agency on the operation and maintenance of their plant.
3. Attempt to convince the owners of the plant on the importance of competent operators and a high priority for plant performance.
4. Although a heavy-handed enforcement approach is undesirable, the plant owners should be reminded of their legal responsibilities.

III. Troubleshooting Guide to Problem 3 (10 Minutes)

A. Identity of Problem

The problem shown is one of poor and uneven distribution of waste over the filter, including clogged nozzles and leaking seals.

KEY POINTS & INSTRUCTOR GUIDE

Show Slides TF-23, TF-24, TF-25, TF-26

Guide: This example was used to illustrate how to deal with small plants that do not receive full time operator attention.

Key Point: discussion should focus on how to troubleshoot small plants with part-time operators.

Show Slides TF-27, TF-28

LESSON OUTLINE | **KEY POINTS & INSTRUCTOR GUIDE**

B. Likely Causes

1. Poor spray pattern on filter
2. Nozzle clogging
3. Leakage of seals
4. Continued or frequent clogging indicates solids carry-over from primaries; may be due to abnormal loadings to plant of grease or suspended solids. During fall of year sewer clogging due to leaves is a possible problem.

C. Effects and Symptoms of Problems.

1. Less efficient waste removal by filter due to uneven loading.
2. Sloughing of filter growths.
3. Ponding on certain areas of filter media and drying on others.

D. Proposed Methods of Correction

1. Adjust splash plates, clean slime growths of plates; replace missing plates.
2. Clean nozzles regularly with small wire or brush, and thoroughly flush distributor piping.
3. Attempt to correct seal leakage problems – which are common. Some seal leakage may be normal.

IV. Troubleshooting Guide to Problem 4 (10 Minutes)

A. Identity of Problem

Show Slides TF-29, TF-30

The slides showed a case of severe filter ponding, which in this case was due to excessive loading without a corresponding high recirculation rate.

Filter Ponding – occurs when voids between filter media are clogged by biological slimes or inert materials.

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

B. Likely Causes

1. Excessive organic loading without corresponding high recirculation rate; organic load too heavy in comparison with hydraulic load.
2. media too small or not sufficiently uniform in size.
3. media deterioration due to improper material selection, or freezing.
4. voids becoming clogged by excessive growth of insect larvae or snails (Perrywinkle snails quite common on filters).

C. Effect and Symptoms of Problems

1. Ponding on filter surface.
2. Intermittent flooding of filter.

D. Proposed methods of correction (For intermittent ponding, caused primarily by excessive loading, or by temporary clogging)

Ponding can be eliminated by several methods. In order of least effect on effluent, corrective measures include:

1. jet surface with high-pressure stream of water.
2. stop distributor over ponded area; flush excessive growth from voids.
3. stir or rake filter surface to lessen or remove any accumulations.
4. dose filter with chlorine at about 5 mg/l for several hours; do during low flow periods to minimize required chlorine dosage (less preferable).
5. if possible, flood filter and allow it to stand for 24 hours; don't let water rise high enough to get into distributor bearings; resulting liquid is a mess to dump (less preferable);
6. if the problem is caused by snails, Malathion can be used to kill snails.

Note: State regulations need to be observed any time pesticides are considered in a treatment plant.

E. Proposed Methods of Correction (for continual ponding)

For continual ponding filter must be dismantled to determine what specific cause is; then take necessary corrective action.

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

1. media too small or non-uniform – screening and/or replacement is in order.
2. media deterioration – media must be replaced!
3. broken or clogged underdrains – flush out underdrain system or remove media and make necessary repairs. In most cases, media replacement will be necessary.

V. Summary and Conclusion (5 Minutes)

   A. Briefly summarize trickling filter operations – and the use of the Process of Troubleshooting to approach operational problems.

   B. Call for any student questions, comments, discussion.

STUDENT NOTEBOOK MATERIALS

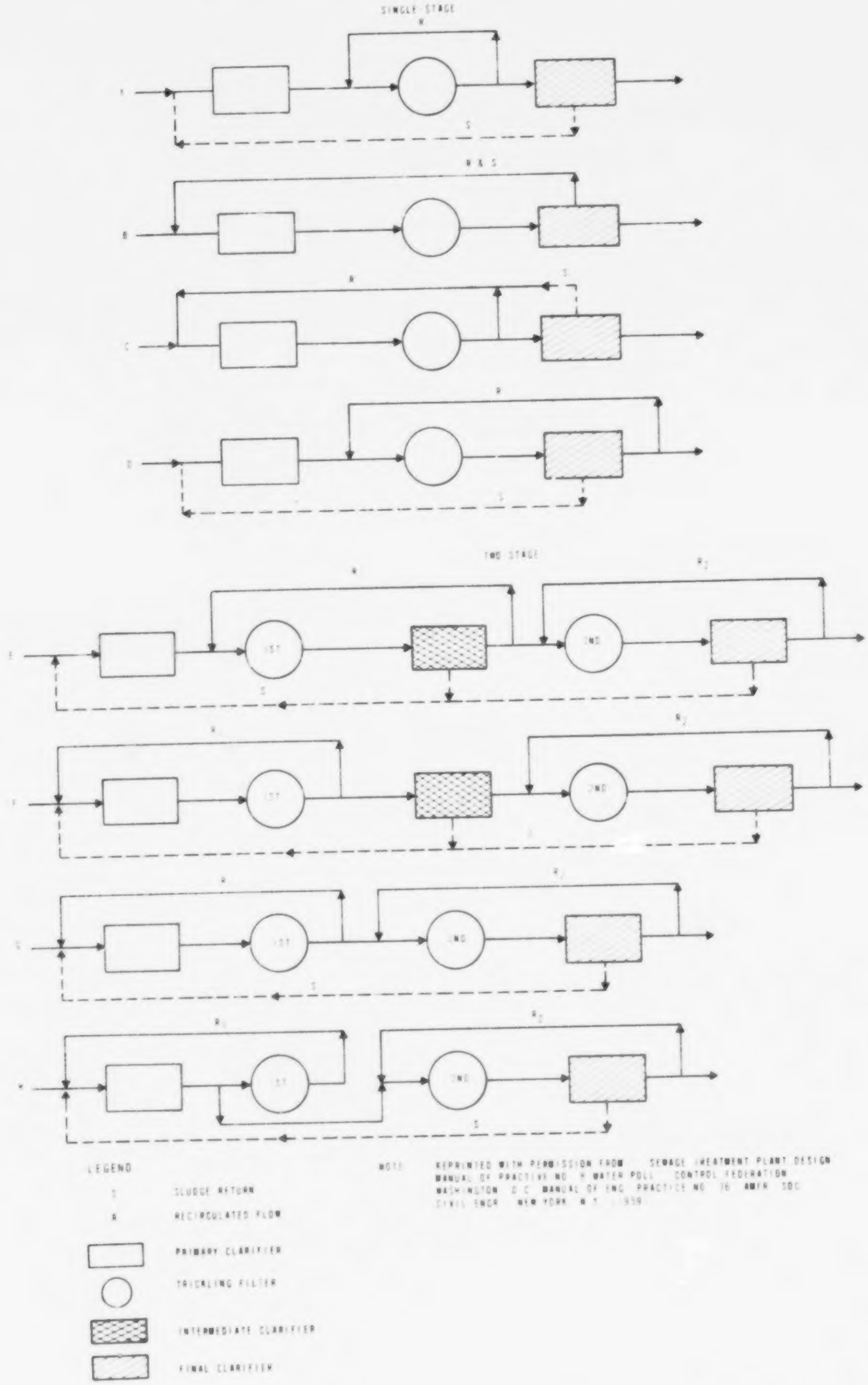
The following materials are included in section 4 of the Student Notebook, Trickling Filters. The Notebook is distributed to students at the start of the course, and is available to them as a reference material throughout the course. Some of these materials are to be used by the instructor as an integral part of the lesson.

Index of Notebook Materials

Pages	Materials	Use in Lesson
TF – 1 thru 5	Flow diagrams relating to upgrading trickling filter plants.*	Referred briefly by instructor. Subdivision 1, Section III.
TF – 6	Answer Sheet, Trouble-shooting Problem.	Used by student groups to answer problems in Subdivision 2. Used also for discussion, Subdivision 3.
TF – 7	References	

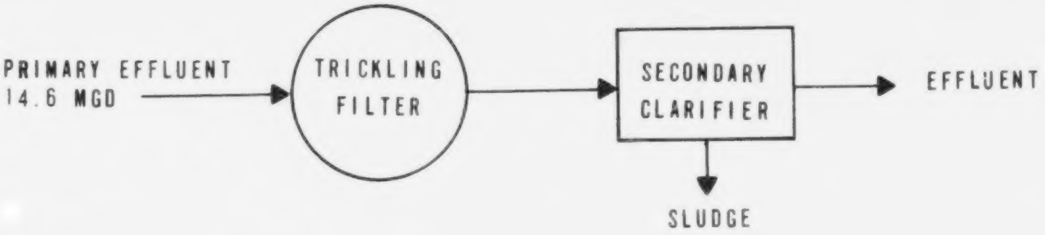
* Reproduced from EPA Manual, "Upgrading Existing Wastewater Treatment Plants," Chapter 4.

COMMON FLOW DIAGRAMS FOR SINGLE AND TWO-STAGE HIGH-RATE TRICKLING FILTERS (2)

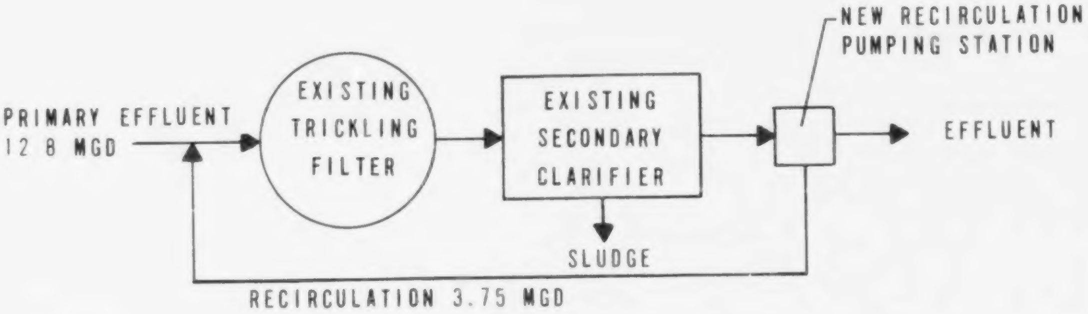

SINGLE-STAGE
R
A
S
R & S
B
R
S
C
R
D
S
TWO STAGE
R
R_2
E
1ST
2ND
S
R
R_2
F
1ST
2ND
S
R
R_2
G
1ST
2ND
S
R_1
R_2
H
1ST
2ND
S
LEGEND
S
SLUDGE RETURN
R
RECIRCULATED FLOW
PRIMARY CLARIFIER
TRICKLING FILTER
INTERMEDIATE CLARIFIER
FINAL CLARIFIER

NOTE: REPRINTED WITH PERMISSION FROM "SEWAGE TREATMENT PLANT DESIGN" MANUAL OF PRACTICE NO. 8 WATER POLL. CONTROL FEDERATION WASHINGTON, D.C. MANUAL OF ENG. PRACTICE NO. 36, AMER. SOC. CIVIL ENGR., NEW YORK, N.Y. (1959)

UPGRADING A SINGLE-STAGE LOW-RATE TRICKLING FILTER BY IMPROVING DISTRIBUTION

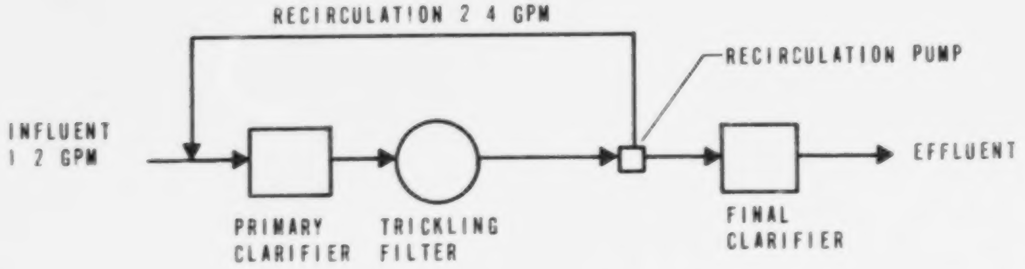

PRIMARY EFFLUENT
14.6 MGD
TRICKLING FILTER
SECONDARY CLARIFIER
EFFLUENT
SLUDGE

TREATMENT SYSTEM BEFORE UPGRADING

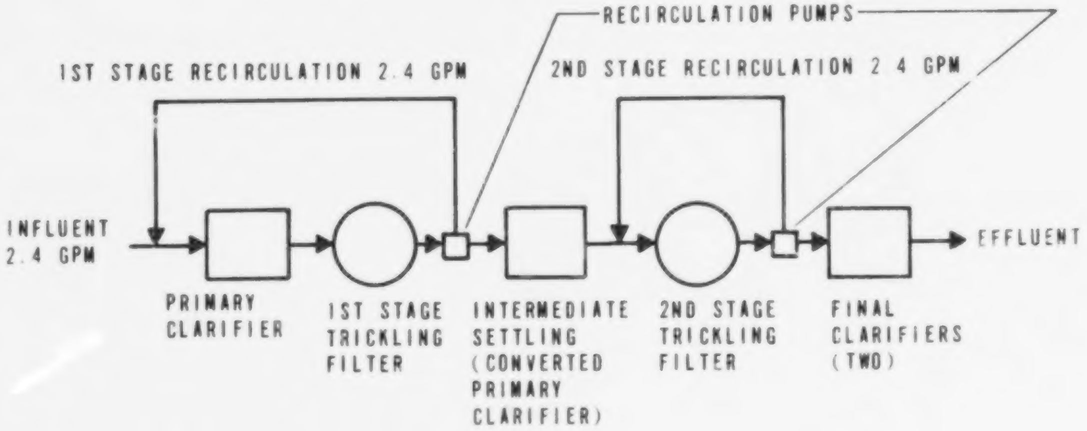

NEW RECIRCULATION PUMPING STATION
PRIMARY EFFLUENT
12.8 MGD
EXISTING TRICKLING FILTER
EXISTING SECONDARY CLARIFIER
EFFLUENT
SLUDGE
RECIRCULATION 3.75 MGD

TREATMENT SYSTEM AFTER UPGRADING

MODIFYING A SINGLE-STAGE TRICKLING FILTER TO A TWO-STAGE FILTRATION SYSTEM

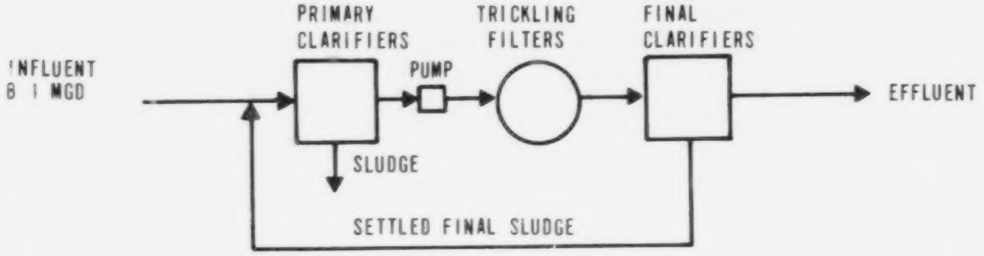

RECIRCULATION 2.4 GPM
RECIRCULATION PUMP
INFLUENT
1.2 GPM
EFFLUENT
PRIMARY CLARIFIER
TRICKLING FILTER
FINAL CLARIFIER

TREATMENT SYSTEM PERFORMING AS
SINGLE-STAGE TRICKLING FILTER SYSTEM
(ONE OF TWO DUPLICATE TRAINS)

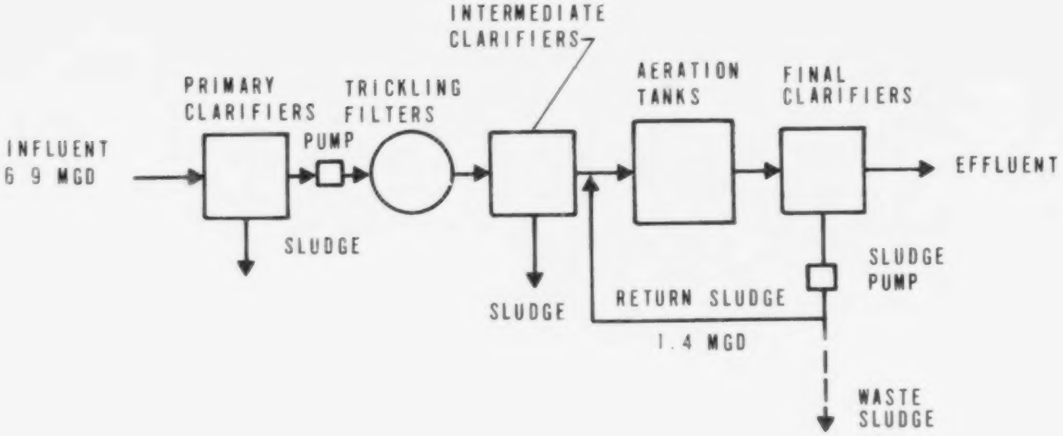

RECIRCULATION PUMPS
1ST STAGE RECIRCULATION 2.4 GPM
2ND STAGE RECIRCULATION 2.4 GPM
INFLUENT
2.4 GPM
EFFLUENT
PRIMARY CLARIFIER
1ST STAGE TRICKLING FILTER
INTERMEDIATE SETTLING (CONVERTED PRIMARY CLARIFIER)
2ND STAGE TRICKLING FILTER
FINAL CLARIFIERS (TWO)

TREATMENT SYSTEM MODIFIED TO
TWO-STAGE TRICKLING FILTER SYSTEM

UPGRADING A SINGLE STAGE TRICKLING FILTER TO A TWO-STAGE BIOLOGICAL FILTRATION/ACTIVATED SLUDGE SYSTEM

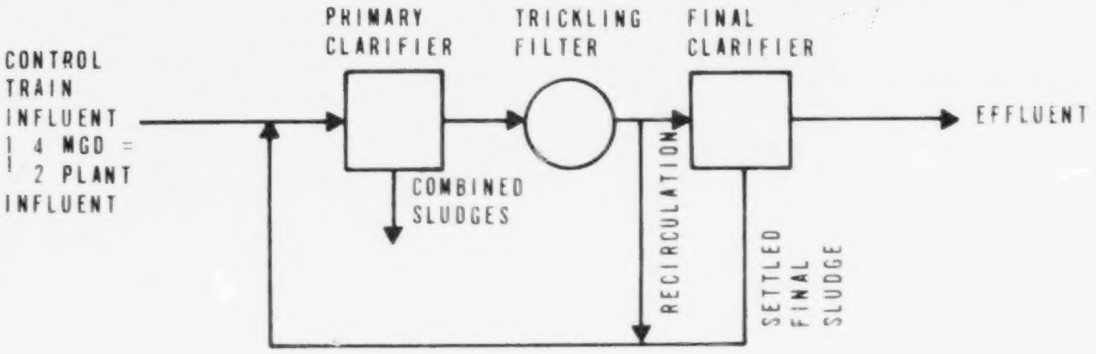

INFLUENT
8.1 MGD
PRIMARY CLARIFIERS
PUMP
TRICKLING FILTERS
FINAL CLARIFIERS
EFFLUENT
SLUDGE
SETTLED FINAL SLUDGE

TREATMENT SYSTEM BEFORE UPGRADING

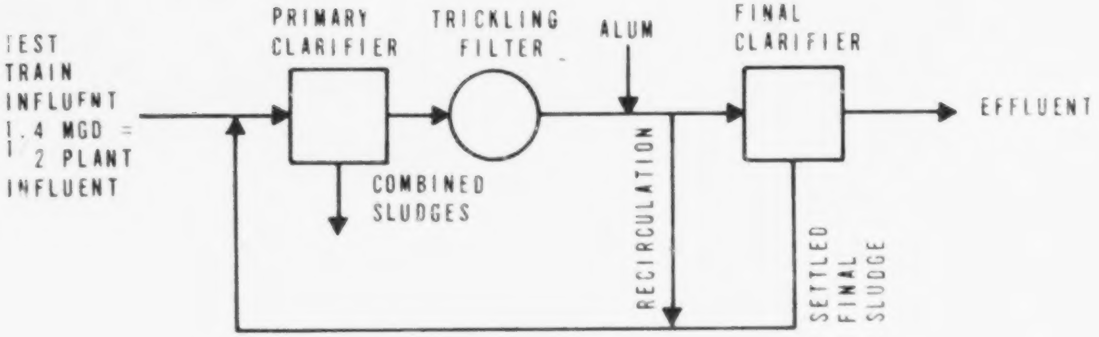

INTERMEDIATE CLARIFIERS
PRIMARY CLARIFIERS
TRICKLING FILTERS
AERATION TANKS
FINAL CLARIFIERS
INFLUENT
6.9 MGD
PUMP
EFFLUENT
SLUDGE
SLUDGE
SLUDGE PUMP
RETURN SLUDGE
1.4 MGD
WASTE SLUDGE

TREATMENT SYSTEM AFTER UPGRADING

UPGRADING A TRICKLING FILTER SYSTEM USING CHEMICAL ADDITION FOR PHOSPHORUS REMOVAL


CONTROL TRAIN INFLUENT
1.4 MGD = ½ PLANT INFLUENT
PRIMARY CLARIFIER
TRICKLING FILTER
FINAL CLARIFIER
EFFLUENT
COMBINED SLUDGES
RECIRCULATION
SETTLED FINAL SLUDGE

TRICKLING FILTER TRAIN WITHOUT CHEMICAL ADDITION


TEST TRAIN INFLUENT
1.4 MGD = ½ PLANT INFLUENT
PRIMARY CLARIFIER
TRICKLING FILTER
ALUM
FINAL CLARIFIER
EFFLUENT
COMBINED SLUDGES
RECIRCULATION
SETTLED FINAL SLUDGE

TRICKLING FILTER TRAIN WITH CHEMICAL ADDITION

ANSWER SHEET

Troubleshooting Problem — Trickling Filters

GROUP NUMBER ______ DISCUSSION LEADER ______

PROBLEM NUMBER

A. STATEMENT OF PROBLEM

B. LIKELY CAUSES

C. EXPECTED EFFECTS AND SYMPTOMS

D. PROPOSED METHODS OF CORRECTION

REFERENCES – TRICKLING FILTERS

Process Design Manual for Upgrading Existing Wastewater Treatment Plants. U.S. EPA Technology Transfer. October. 1974.

Procedural Manual for Evaluating the Performance of Wastewater Treatment Plants. U.S. EPA URS Research Company.

Clark. J.W., W. Viessman. Jr., and M.J. Hammer. Water Supply and Pollution Control. International Textbook Company. 1971. 2nd Edition.

Manual of Wastewater Operations. Texas Water Utilities Association. Lancaster Press. Inc. 1971. 4th Edition.

Manual of Instruction for Sewage Treatment Plant Operators. New York State Department of Health. Distributed outside of New York State by Health Education Service. P.O. Box 7283. Albany. New York 12224.

Operation of Wastewater Treatment Plants. Water Pollution Control Federation No. 11, Water Pollution Control Federation. 1970.

Operation of Wastewater Treatment Plants. A Field Study Training Program. California State University. Sacramento.

Wastewater Engineering: Collection. Treatment. Disposal. Metcalf & Eddy. Inc. McGraw-Hill Book Company. 1972.

Hanumanulu. V., Effect of Recirculation on Deep Trickling Filter Performance. Journal Water Pollution Control Federation. 41. 1803. 1969.

Hawkes. H.A.. and R.N. Shephard. The Effect of Dosing Frequency on the Seasonal Fluctuations and Vertical Distribution of Solids and Grazing Fauna in Sewage Percolating Filters. Water Research. 6. 721. 1972.

DeRuitar. H., Control of Psychoda Flies. Water and Sewage Works. Volume 107. No. 6. 211. 1960.

LESSON – OXIDATION LAGOONS

Instructor Overview of Lesson

Entry Level Behavior: Students will have had University training in Sanitary Engineering, waste treatment and/or related sciences or equivalent in experience and training. Some field experience in inspecting oxidation lagoons, but none in operating waste treatment facilities.

As a prerequisite to this course, it is recommended that the student will be able to –

1. Identify treatment plant process units
2. Describe treatment plant process units and equipment in technical terms
3. Identify and explain the purpose of components of treatment plant process units, how they work and why they are important to the overall process
4. Describe the normal operating procedures for treatment plant process unit components
5. Identify when treatment plant process units are not operating properly

Instructor Objectives: The principal instructor objectives for this lesson are:

1. To provide the basic elements of the Process of Troubleshooting as it relates to operational problems in oxidation lagoons
2. To stress the use of the Process of Troubleshooting as a valuable tool to upgrade lagoon performance
3. To provide a realistic student problem in the operation of oxidation lagoons
4. To stimulate class discussion on the approach to the student problem on troubleshooting oxidation lagoons

References: Note list of references included with Student Notebook materials

Total Length of Lesson: 1 hour, 45 minutes for 3 lesson subdivisions

LESSON OVERVIEW

Subdivision Title & Time	Major Student Objectives	Key Points & Content	Approaches	Materials
1. Troubleshooting Oxidation Lagoons 30 Minutes	1. Describe lagoon properties & characteristics. 2. Recognize & identify lagoon problems. 3. List problem causes. 4. Know corrective actions for lagoon problems. 5. Identify means of upgrading lagoons.	1. Lagoon characteristics. 2. Trouble indicators. 3. Tests & analyses. 4. Troubleshooting Guide. 5. Methods of upgrading lagoons.	1. Follow subject outline. Use prepared slide series. Seek student input in following subject outline.	1. Slide series & slide key. 2. EPA Manual 3. Student Notebook.
2. Applying the Process of Troubleshooting 45 Minutes	1. Follow systematic approach to solving lagoon problems. 2. Determine troubleshooting data, nature of problem and likely cause. 3. Recommend actions to correct lagoon operating problem.	1. Students are presented a realistic problem in lagoon operations, which they must approach, think through, and solve.	The assigned problem has three stages, in which the students must: 1. Decide how to approach the problem. 2. Determine what the problem is. 3. Recommend problem corrections. Students work in predetermined groups.	Each student group receives 3 problem/answer sheets with all information needed to work on this problem, distributed by the instructor.
3. Problem Reporting and Analyses 30 Minutes	1. Compare approaches to assigned problem, and consider the merits of alternative approaches.	1. Stress the systematic approach to troubleshooting lagoon problems. 2. Stress the need to talk and work with people on solving problems.	Maximum student discussion of problem assigned in Subdivision 2. Lesson outline provided to guide class discussion.	Problem/anser sheets used in Subdivision 2.

LESSON – OXIDATION LAGOONS

Presentation Options for Course Director

Oxidation lagoons are the single most prevalent waste treatment facility in the U.S. They are particularly prevalent in Regions IV (Atlanta – 1,500 lagoons), V (Chicago – 753 lagoons), VI (Dallas – 704 lagoons), VII (Kansas City – 1,029 lagoons) and VIII (Denver – 749 lagoons). On the other hand, they are very uncommon in certain areas, particularly Region I (Boston – 16 lagoons) and Region II (New York – 4 lagoons). Therefore, the significance of this lesson obviously varies and is dependent upon the location of the course and the points of origin of the students.

In most regions of the country, this 1 hour, 45 minute lesson on OXIDATION LAGOONS is appropriate in relation to a total course of effort of between 28 and 40 hours. It is recommended that the length of this lesson not be reduced in time. If it is felt not to be significant for the particular session of the course being offered, it would be better to eliminate the lesson entirely than to shorten it, which would considerably reduce its effectiveness. On the other hand, there are several opportunities to modify the lesson, or to add to it as desired by the Course Director, as follows:

Subdivision 1 – Troubleshooting Oxidation Lagoons: Where additional information is desired, this subdivision can easily be expanded to 45 or 60 minutes, by following the basic outline provided in the lesson plan materials. The slides provided may be supplemented by slides of lagoons from the area where the course is being presented. Section III, Upgrading Oxidation Lagoons, can be expanded considerably if desired by the Course Director. Additional material on operating aerated lagoons can also be provided.

Subdivision 2 – Applying the Process of Troubleshooting: This is a very important student exercise, and should be presented according to the lesson plan outline.

Subdivision 3 – Problem Reporting and Analysis: This subdivision follows directly from Subdivision 2, and includes the review and discussion of the problem assigned to the student groups. This subdivision should not be reduced in time, and may be expanded if the Course Director feels that additional time should be devoted to the student troubleshooting exercise.

OXIDATION LAGOONS

LESSON PLAN – SUBDIVISION 1 **TIME: 30 MINUTES**

Title: Troubleshooting Oxidation Lagoons

Instructor Objectives: To provide for the students the basic elements of the Process of Troubleshooting as it relates to operational problems in oxidation lagoons. To stress the use of the Process of Troubleshooting as a value tool to upgrade lagoon performance.

Student Objectives: As a result of this lesson subdivision, students will be able to do the following:

1. List and describe the principal characteristics of oxidation lagoons, and their expected performance
2. Identify uncontrollable factors in operating oxidation lagoons
3. Recognize and explain trouble indicators, and visual observations necessary for troubleshooting lagoons
4. List and conduct tests and analyses for troubleshooting lagoons
5. List and identify the most common problems in operating lagoons, and their causes
6. List and explain corrective actions to be implemented to solve operational problems in oxidation lagoons
7. Describe the overall Process of Troubleshooting as applied to oxidation lagoons
8. Engage in "creative troubleshooting" to correct problems in oxidation lagoons
9. List means of upgrading lagoon performance
10. Describe seasonal flow patterns recommended for two-stage lagoons
11. List and explain the major characteristics of aerated lagoons

Training Materials:

Slide series, word and picture slides, with slide key

EPA Manual "Evaluating the Performance of Wastewater Treatment Plants," particularly pp 77-79

Student Notebook section on Oxidation Lagoons

Process of Troubleshooting Chart

Classroom Set-up:

A normal classroom set-up will be required. Students should be seated with their student groups

35 mm carousel slide projector with remote controls

Large screen (8 ft x 10 ft)

Chalkboard or easel

Pointer

Subdivision Schedule:

Within the 30 minute time period, the following schedule should be observed in presenting the lesson plan outline

TIME	SUBJECT
0 – 5 Minutes	Characteristics of Oxidation Lagoons
5 – 20 Minutes	Troubleshooting Lagoon Problems
20 – 25 Minutes	Upgrading Oxidation Lagoons
25 – 30 Minutes	Questions and Discussion

Subdivision Approach:

The instructor is to rely upon the lesson outline, and particularly upon the slide series and slide key

The instructor should seek student input in following the outline, particularly with regard to the word slides that call for student participation in the instructor's guide

The material presented in the outline should be presented in the context of the overall Process of Troubleshooting, and how this systematic process can be used to solve operating problems.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
I. Characteristics of Oxidation Lagoons (5 Minutes) Use sequence of word and picture slides as follows:	
A. "TROUBLESHOOTING OXIDATION LAGOONS"	SLIDE OL-1 (word)
B. "CHARACTERISTICS OF LAGOONS"	SLIDE OL-2 (word)
• Natural processes occur under controlled conditions • Reliable treatment at minimum cost • Maintenance simple, but necessary • Frequent observation necessary	
C. Visual observations tell a lot about the condition of a lagoon, such as this installation which is well-maintaineed	SLIDE OL-3 (picture)
D. And this one which is not! (See if class can identify what is wrong with this lagoon – poor weed control)	SLIDE OL-4 (picture) Guide: Both slides are taken in Northwest Ohio late winter.
E. "UNCONTROLLABLE FACTORS IN OPERATING OXIDATION LAGOONS"	SLIDE OL-5 (word)
• Visible light • Temperature • Wind • Ice cover	
F. "EXPECTED PERFORMANCE OF OXIDATION LAGOONS"	SLIDE OL-6 (word)
• Green-clear effluent • No scum, grease in effluent • BOD below 30 mg/l on filtered sample • Algae likely in effluent • Normally won't meet secondary effluent requirements	Key Point: Common parameters are questionable in assessing lagoon performance. For example – BOD's on lagoon effluents may vary from place to place.
1. Slides show color of lagoons that would *appear* to be healthy	SLIDE OL-7, OL-8
Note that slides sometimes can't represent true color	Guide: Both slides are taken in Minnesota at healthy lagoons.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
II. Troubleshooting Lagoon Problems (15 Minutes)	
A. "TROUBLE INDICATORS OF LAGOONS" • Color changes to dull green, black, or gray • Unpleasant odors • Excessive fecal coliforms discharged • Unstable organics are discharged	SLIDE OL-9 (word)
Example of an indicator of trouble – lagoon color	SLIDE OL-10 (picture) Scene shows a lagoon going septic
B. "OBSERVATIONS – FOR TROUBLESHOOTING LAGOONS" • Color, important sign of lagoon condition • Flow, is lagoon overloaded or short circuiting? • Water depth • Aerator performance (in aerated lagoons) • Maintenance activity	SLIDE OL-11 (word)
C. "TESTS AND ANALYSES FOR TROUBLESHOOTING LAGOONS"	SLIDE OL-12 (word) Use this slide to ask for class input as to what tests should be run in troubleshooting lagoons
D. "TESTS AND ANALYSES FOR LAGOONS" • DO, diurnal variation • pH • Temperature profile • Suspended solids • Fecal coliforms • Sulfides – if there are industrial waste problems	SLIDE OL-13 (word)
E. "MOST COMMON LAGOON PROBLEMS" • Excessive weeds, often related to mosquitos • Odors • Short circuiting • Low DO	SLIDE OL-14 (word)
F. "PROBLEM – EXCESSIVE WEEDS, MOSQUITOS" • Likely cause: • Things to monitor: • Corrective action:	SLIDE OL-15 (word) Have students contribute – then go to next slide with completed information

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
G. "PROBLEM – EXCESSIVE WEEDS, MOSQUITOS"	
• Cause: Poor circulation, maintenance	SLIDE OL-16 (word)
• Monitor: depth, flow	
• Correction: Remove weeds, deepen pond, fluctuate level	
1. Views of common problems with weeds	
a. Weeds around lagoon border	SLIDE OL-17 (picture)
b. Weeds within pond – Permer, Minnesota	SLIDE OL-18 (picture)
c. Lagoons "choking" pond – Parkers Prairie, Minnesota	SLIDE OL-19 (picture)
H. "PROBLEM – ODORS"	SLIDE OL-20 (word)
• Likely cause:	Have students contribute
• Things to monitor:	
• Corrective action:	
I. "PROBLEM – ODORS"	SLIDE OL-21 (word)
• Cause: hydrogen sulfide, industrial wastes	
• Monitor: pH, DO, algae, scum, sulfides	
• Correction: Aeration, prechlorination, eliminate septic or industrial inflows	
J. "PROBLEM – SHORT CIRCUITING"	SLIDE OL-22 (word)
• Likely cause:	Have students contribute
• Things to monitor:	
• Corrective Action:	
K. "PROBLEM – SHORT CIRCUITING"	SLIDE OL-23 (word)
• Cause: wind action, hydraulic overloading, inlet and outlet locations	
• Monitor: Flow, DO, detention time, temperature distribution	
• Correction: Recirculate, increase mixing, provide new inlets and outlets	
L. "PROBLEM – LOW DISSOLVED OXYGEN"	SLIDE OL-24 (word)
• Likely cause:	Have students contribute
• Things to monitor:	
• Corrective action:	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
M. "PROBLEM – LOW DISSOLVED OXYGEN"	SLIDE OL-25 (word)
• Cause: industrial waste, detention time, poor light penetration • Monitor: DO, flow, pH, sulfide, loading rate • Correction: increase detention, go to parallel operation, aerate, remove weeds	For more troubleshooting details, refer students to EPA Manual, "Evaluating the Performance of Wastewater Treatment Plants,"pp 77-79.
N. "MOST LAGOON PROBLEMS CAN BE SOLVED WITH:"	Summarize Lagoon Troubleshooting SLIDE OL-26 (word)
• Visual observations • Simple tests and analysis • "common sense" corrective actions i.e. – systematically applying the PROCESS OF TROUBLESHOOTING	
O. "CREATIVE TROUBLESHOOTING FOR LAGOONS INVOLVES"	SLIDE OL-27 (word)
• A "hands-on" approach • Using spare materials and equipment • Innovative "jury rigging" to achieve results	Ask students for their ideas on creative troubleshooting"
1. Scene depicting use of portable equipment to solve a lagoon problem. (This happens to be a sludge lagoon.)	SLIDE OL-28 (picture)
P. Scenes of another common lagoon problem	
1. Gradual dike erosion (Rose Creek, Minn)	SLIDE OL-29 (picture)
2. Severe erosion (Sleepy Eye, Minn)	SLIDE OL-30 (picture)
3. Erosion protection (Ada, Minn)	SLIDE OL-31 (picture)
4. Erosion protection – Rip Rap (Sartell, Minn)	SLIDE OL-32 (picture)
III. Upgrading Oxidation Lagoons (5 Minutes)	
A. EPA Reports indicate that 1. Single cell lagoons can't meet EPA 30/30 requirements 2. Many lagoons not performing up to design standards 3. Therefore, upgrading of lagoons is often an attractive alternative	
B. "UPGRADING ALTERNATIVE, IN ORDER OF EFFECTIVENESS"	SLIDE OL-33 (word)
• Improve operations, minor modification • Modify operating mode • Modify design	

LESSON OUTLINE

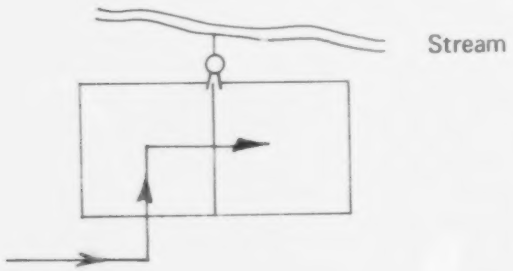
C. " UPGRADING LAGOONS THROUGH IMPROVING OPERATIONS"

- Prevent short circuiting
- Operate inlets and outlets flexibly
- Prevent organic overloads
- Eliminate weeds, improve maintenance

D. "UPGRADING LAGOONS THROUGH MODIFYING OPERATIONS"

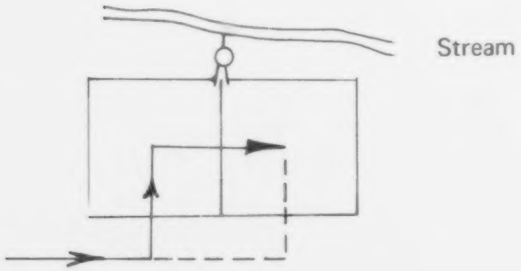
- Supplemental aeration
- Develop seasonal flow patterns for two stage lagoons

1. Schematics of seasonal flow patterns



SUMMER (July, August, September)

1. Flow Pattern: Series
2. Depth: 5 ft



FALL (October, November December)

1. Flow Pattern:
   Oct., Nov. – Series
   Dec. Parallel
2. Depth: Lower to 2½ - 3 ft
3. Effluent: Shut off (Dec)

KEY POINTS & INSTRUCTOR GUIDE

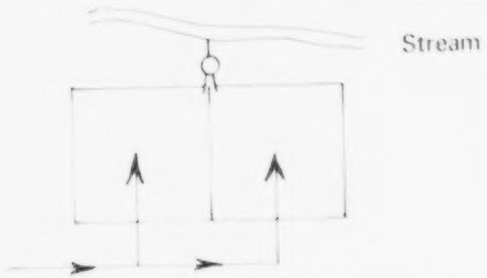
SLIDE OL-34 (word)

SLIDE OL-35 (word)

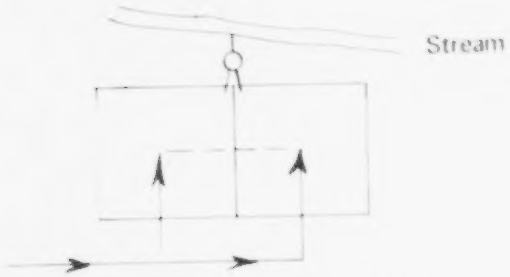
SLIDE OL-36 (word)
Refer students to fact that these diagrams are provided in Student Notebook

SLIDE OL-37 (word)

LESSON OUTLINE



WINTER (January, February, March)
1. Flow Pattern: Parallel
2. Effluent: Off
   (Hold All Flow)



SPRING (April, May, June)
1. Flow Pattern:
   Apr., May — Parallel
   June — Series
2. Depth: 5 ft

E. "UPGRADING LAGOONS THROUGH MODIFYING DESIGN"
- Polishing techniques, rock and sand filters
- Add capacity, additional cells
- Add flexibility, inlets, outlets
- Go to full time mechanical aeration

KEY POINTS & INSTRUCTOR GUIDE

SLIDE OL-38 (word)

SLIDE OL-39 (word)

SLIDE OL-40 (word)

Key Point: Mechanical aeration requires major changes

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
F. "CHARACTERISTICS OF AERATED LAGOONS"	SLIDE OL-41 (word)
• Actually a variation of activated sludge • Requires a secondary settling • Depths of 10 ft to 20 ft • Use surface aerators or diffused air • Aerators must be properly secured	
1. Scenes of aerated lagoons	
a. Aeration system in place — diffused air	SLIDE OL-42 (picture)
b. Same system operating — Grand Rapids, Minnesota	SLIDE OL-43 (picture)
c. Aerated lagoon using surface aerators	SLIDE OL-44 (picture)
IV. Questions and Discussion (5 minutes)	Encourage class participation and discussion

OXIDATION LAGOONS

LESSON PLAN – SUBDIVISION 2 **TIME: 45 MINUTES**

Title: Applying the Process of Troubleshooting

Instructor Objectives: To provide a realistic problem in the operation of oxidation lagoons for student groups to analyze and solve by applying the elements of the Process of Troubleshooting.

Student Objectives: As a result of this lesson subdivision, students will be able to do the following:

1. Follow a systematic approach to the solving of operational problems in oxidation lagoons by applying the elements of the Process of Troubleshooting.
2. Determine which observations, data, and other information are needed to apply the Troubleshooting Process to solving operating problems in oxidation lagoons.
3. Identify and describe the nature of a specific operating problem in oxidation lagoons given detailed design and operating factors, visual observations and test analyses.
4. Determine the likely cause of a specific operating problem in oxidation lagoons given detailed design and operating factors, visual observations and test analyses.
5. Recommend alternative actions for immediate and long range solutions to a specific operating problem in oxidation lagoons.

Additionally, it is the objective of this lesson subdivision that students learn to analyze and solve operational problems through group activity, and that they learn to work with others in solving treatment plant problems.

Training Materials:

Each student group will be distributed three (3) problem/answer sheets to be used to work on this problem. The first sheet is to be distributed at the start of the allotted time period. The remaining two sheets are to be handed out after 20 minutes. (Problem/answer sheets are instructor's lesson plan pages OL 2-4 thru OL 2-6)

Classroom Set-up:

The classroom is to be set up for four (4)-person groups sitting together to work on the assigend problem. Card tables, or other means of separating groups from one another are preferable.

Subdivision Schedule:

Within the 45 minute time period, the following schedule should be observed.

TIME	ACTIVITY
0 – 5 Minutes	Introduce problem, distribute problem/answer sheet No. 1
25 Minutes	Hand out problem/answer sheets No. 2 and No. 3
30 – 35 Minutes	Check group findings for second stage. Have groups go on to third stage of problem, problem/answer sheet No. 3
45 Minutes	Call time, move to lesson subdivision 3

Subdivision Approach

Students are to be arranged in four (4)-person groups. Each student is expected to participate fully within his group in order to analyze and solve the assigned problem.

The problem is to be approached by the students in 3 stages, as reflected in the problem/answer sheets, as follows.

First Stage: Students are given problem/answer sheet No. 1, which contains very little information, only that there is a 2-pond oxidation lagoon which has been operating sporadically with variable results. Student groups are to fill out first answer sheet which requires them to figure out *how* they would *approach* the problem.

Second Stage: After 20 minutes, student groups are given the second problem/answer sheet which contains data obtained by observing, testing and analyzing the problem. In the second stage, students are to determine *what the nature* of the problem is (it is one of short circuiting and inadequate detention time) and what it may be caused by. Once this is determined, they are to check with the instructor (one group at a time) before proceeding to the third stage.

Third Stage: Student groups are to recommend *possible corrections* to the problem, and spell out what they would continue to observe and test for in order to verify that the problem had been corrected.

As the student groups complete stage two, if they are not on the right track as to what the problem is, the instructor should meet with them and given them enough assistance to allow them to go on to Stage 3.

The instructor should announce at the start of the subdivision that students may refer to the EPA Manual "Evaluating the Performance of Wastewater Treatment Plants" if they find it necessary, but we would prefer that they try to solve the problem independent of references.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE

I. Prior to start of lesson subdivision

  A. Student groups should be designated by Course Director or instructor

  B. Problem/answer sheets 1-3 (lesson plan pages OL 2-4 through OL 2-6 should be duplicated – one for each student)

II. Introduction to lesson subdivision (5 minutes)

  A. Distribute problem/answer sheet No. 1

  B. Introduce problem, describe stage 1

III. Stage 1 (20 minutes)

  A. Instructor should circulate from group to group to answer questions where necessary

IV. Stage 2 (5-10 minutes)

  A. Distribute problem/answer sheets No. 2 and No. 3

  B. After 5 minutes check group findings, i. e., have they identified the problem? If so, let them go on to the third stage and answer sheet No. 3

V. Stage 3 (10-15 minutes)

  A. For any group that has not completed the second stage satisfactorily within a 10 minute period, give them enough assistance to move on to the third stage

  B. Instructor should remain available to answer questions

  C. Call time at the end of 45 minutes, and move on to Subdivision 3, Problem Reporting and Analysis

Stage 1. Problem/Answer sheet No. 1
To be handed out to students

TROUBLESHOOTING PROBLEM – OXIDATION LAGOONS

GROUP ________________

PROBLEM: It is reported to you that a treatment facility using oxidation lagoons for secondary treatment has been operating sporadically with highly variable results. At the time you are called it is operating poorly. The facility has two faculative lagoons that can be operated both in series and in parallel, serving a community of 1,200 people. There are no industrial wastes discharged into the plant.

On this answer sheet, we are concerned about what actions you would take as a troubleshooter in order to be able to assist in solving this problem. Answer the following questions. (You may use additional sheets of paper if necessary.)

1. Who would you talk to about the performance of the plant?
2. What information would you seek about the design and layout of the lagoons?
3. What records would you look at?
4. What references, texts or persons would you consult with?
5. What questions would you ask about plant operations?
6. Make a list of what constituents you would test for and where you would sample.

CONSTITUENTS	SAMPLE LOCATION

7. What visual observations would you take and what would you look for?
8. What other information would you need?

You have 20 minutes to complete this stage of the problem!

Stage 2. Problem Fact/Answer Sheet No. 2
To be handed out to students.

.TROUBLESHOOTING PROBLEM – OXIDATION LAGOONS

GROUP ____________

PROBLEM: Given the following information you have learned during your visit to the plant:

1. Identify and describe the nature of the plant's operational problem
2. Determine the likely causes of the problem

During your investigation (Stage No. 1) you learn the following about the oxidation lagoon in question.

Design and loading factors:

Depth – 4 feet, Design detention time – 25 days, Design loading – 20 lb/acre/day

Hydraulic design capacity – 150,000 gpd

Normal operation at design capacity – lagoons in parallel

Prevailing winds – from west to east

Normal operating conditions and performance:

BOD – Influent – 200 mg/l, Effluent 45 mg/l

SS – Influent – 300 mg/l, Effluent 50 mg/l

Algal concentration – Effluent – 25 mg/l in suspension

pH – Effluent – 9.5, DO – Effluent – supersaturated – daylight hours

Color – Effluent – deep green

Conditions as of 4:00 PM, day after you arrive, after sampling and testing:

BOD – Effluent – too early to tell, SS – Effluent – 95 mg/l

Algal concentration – Effluent 55 mg/l in suspension

pH – Effluent – 7.3, DO – Effluent – 4.5

Temperature: Air – 65°, water at surface 69°, water at bottom 62°

Coliforms – you have no immediate reading, but total effluent coliforms have risen in last 5 days to very high values

Visual Observations and other information learned:

Color of effluent: dull green/gray – Buildup of scum at outlet of ponds
Lagoons are being operated in parallel

Location of inlets: northeast and southeast corners of two lagoons

Location of single outlets to each lagoon – west side

Prior weather: abnormally high rains during the previous 10 days due to a large tropical storm, and local showers. Predominant winds from northeast to southwest

Flows: Measured flow at time of your arrival is 180,000 gpd. However, discussions with plant staff on weir levels during recent days indicate there were probably flows as high as 320,000 gpd due to stormwater infiltration and local flooding

Plant history: you learn that plant operates with poor removal efficiencies about 30% of the time

STOP! Consult with instructor before going on to Sheet No. 3

LESSON PLAN – SUBDIVISION 3 **TIME: 30 MINUTES**

Title: Problem Reporting and Analysis

Instructor Objectives: To stimulate discussion between student groups and among all members of the class on the approach to the problem on oxidation lagoons presented in lesson subdivision 2. To provide students with specific answers to the three problem stages presented in lesson subdivision 2. To stress the relevance and appropriateness of the elements of the systematic troubleshooting process in solving an oxidation lagoon operating problem.

Student Objectives: As a result of this lesson subdivision, students will be able to do the following:

1. Compare the approach of their groups to the presented problem in oxidation lagoons to the approaches presented by other groups.
2. Compare the approach of their groups to the presented problem in oxidation lagoons to the answers provided by the instructor.
3. Consider the merits of alternative approaches to troubleshooting a problem in the operation of an oxidation lagoon.

Additionally, students will have the opportunity to present their approaches for review by the remainder of the class, and to substantiate their approach by arguing its merits. This lesson subdivision provides the students with the opportunity to receive feedback on their problem approaches.

Training Materials:

Problem/Answer Sheets used in lesson subdivision 2.

Classroom Set-up:

Group set-up, same as for lesson subdivision 2.

Stage 3. Problem/Answer Sheet No. 3
To be handed out to students

TROUBLESHOOTING PROBLEM – OXIDATION LAGOONS

GROUP ____________

PROBLEM: Having adequately identified the problem and its causes:

1. Spell out actions* you would take to correct the plant operating problems
   a. Alternative actions for immediate results (in order of priority)

   b. Long-range actions to prevent a recurrrence

*In answering question No. 1, you have available to you –

2 portable pumps
discarded, but useable fire hose
lightweight plastic pipe
assorted sizes and shapes of wood, i.e., 2 x 4's, etc.
earth moving equipment
a small boat with outboard motor
alum and poly-electrolytes
portable chlorine applicator

2. What sampling and testing would you conduct once corrective action is taken? For how long?

3. For how long would you follow up on the plant's performance and be concerned about its effectiveness? Why? What method would you use to follow up?

Subdivision Schedule:

Within the 30 minute time period, the following approximate schedule should be observed:

TIME	ACTIVITY
0 – 5 Minutes	General discussion and comments from class regarding oxidation lagoon problem
5 – 10 Minutes	Discuss answers to stage 1 with class
10 – 15 Minutes	Discuss answers to stage 2 with class
15 – 20 Minutes	Discuss answers to stage 3 with class
20 – 30 Minutes	Review with class the general principles of the systematic process of troubleshooting, and use the elements of the Process of Troubleshooting to summarize this lesson
30 Minutes	Call time, collect problem/answer sheets from each group

Subdivision Approach:

The approach to this lesson subdivision calls for as much student discussion as possible. The instructor is to serve as a catalyst to guide the class discussion, which should center on the following areas:

1. The assigned problem on troubleshooting and oxidation lagoon operating problem
2. Oxidation lagoons in general
3. The applicability and use of the Process of Troubleshooting

The following lesson outline should be used to guide class discussion for this lesson subdivision.

LESSON OUTLINE

I. Generate comments and discussion from class regarding the assigned problem

II. Answers to problem Stage 1 (5 minutes)

1. Who to talk to: Plant operator, other plant personnel, any other possible observers of past plant performance.
2. Information: Design capacity, hydraulic and organic load, detention time.
3. In Records: Flow records, NPDES Monitoring records and any in-plant process testing records. Records of complaints if they are kept.
4. References: O&M manual, if there is one. EPA Manual, "Evaluating the Performance of Wastewater Treatment Plants."
5. Questions:
   a. Describe normal operations — normal effluent quality and lagoon properties
   b. Recent occurrences — ask questions to learn what has taken place leading up to present conditions
6. Parameters sampled: minimum — lagoon and effluent pH, DO, suspended solids. (Interestingly, two EPA manuals differ on what should be sampled)
7. Visual Observations: color — deep green is good

   grey or black is bad

   wind direction

   scum at outlet

.KEY POINTS & INSTRUCTOR GUIDE

Guide. Use opening 5 minutes to "warm up" for discussion.

Key Points: Stress systematic approach.

Stress the need to talk to people, and to get needed information.

LESSON OUTLINE

III. Answers to problem stage 2 (5 minutes)

1. Regardless of how the troubleshooter expresses it, the problem is one of inadequate detention time — caused by short circuiting

2. Likely causes of problem
   - a. Parallel rather than series operation of two lagoons
   - b. Recent hydraulic overload
   - c. Wind direction
   - d. Location of inlet and outlet
   - e. Inflexibility of plant — prevents operator from making adjustments due to weather and hydraulic conditions
   - f. Thermal stratification within the lagoons

IV. Answers to problem stage 3 (5 minutes)

1. Actions to take
   - a. Immediate
     - 1. Change to series operation
     - 2. Use pumps and hose or pipe to recirculate within lagoons to prevent short-circuiting
     - 3. Skim outlet to remove scum
     - 4. Create other means to achieve better mixing
   - b. Long range
     - 1. Use available earth moving equipment and wood to construct additional outlets, allowing for variable discharge depth
     - 2. Construct additional inlets
     - 3. Install floating scum baffles at outlets
     - 4. Erect baffling and other mixing devices to gain maximum detention time

2. Sampling and Testing — standard process control plus effluent monitoring tests

   pH, Do, suspended solids, temperature

KEY POINTS & INSTRUCTOR GUIDE

Key Points: Analyze available information to determine possible causes of plant problem.

List alternatives until the most likely cause is found.

Key Points: Actions can be taken to immediately correct plant problems. Other actions can be taken to prevent recurrences and to upgrade overall plant performance.

Stress the importance of follow-up, and of documenting the results of the troubleshooting actions.

LESSON OUTLINE

3. Follow-up periodically – perhaps monthly or quarterly – with a phone call. Review NPDES monitoring reports

V. Summarize – Application of the Key Elements of Troubleshooting to this Problem (10 minutes)

1. Developing a relationship with plant operator
2. Obtaining and analyzine needed information
3. Formulating alternatives
4. Observing the results of corrective actions
5. Long-range implementation and follow-up

KEY POINTS & INSTRUCTOR GUIDE

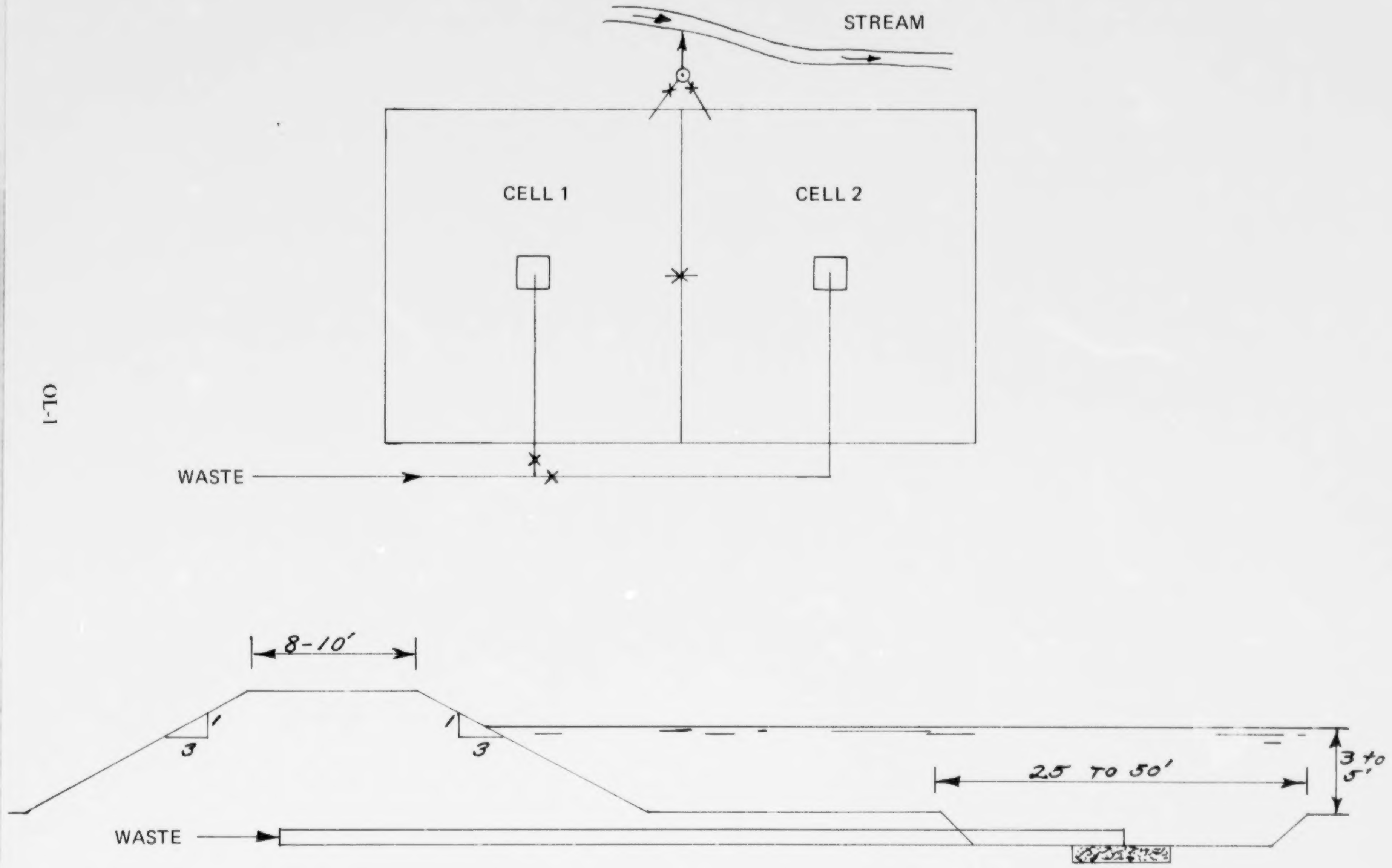
Key Points: Systematic approach to troubleshooting and problem solving.

STUDENT NOTEBOOK MATERIALS

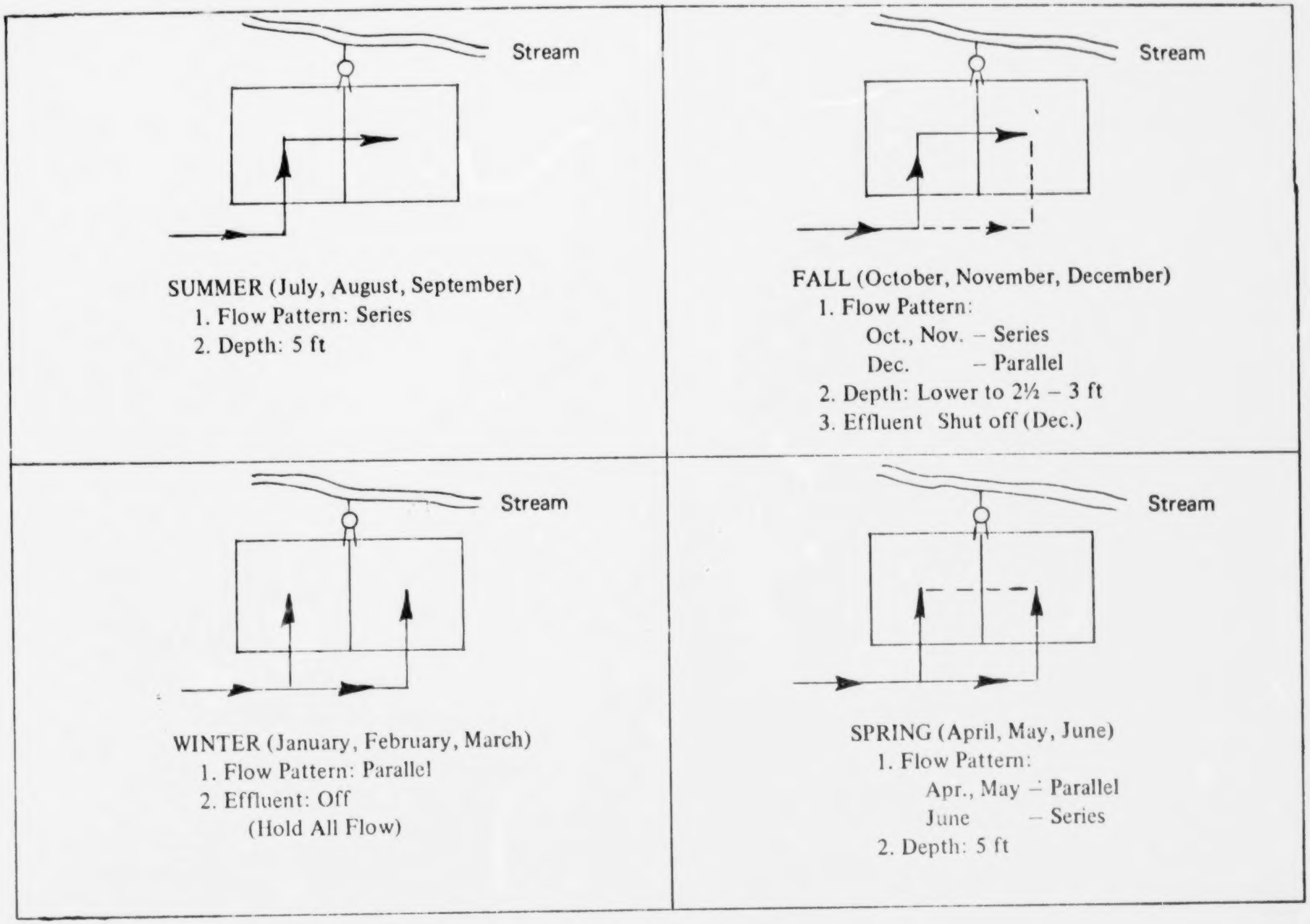
The following materials are included in Section 5 of the Student Notebook, Oxidation Lagoons. The Notebook is distributed to students at the start of the course, and is available to them as a reference material throughout the course. Some of these materials are to be used by the instructor as an integral part of the lesson.

Index of Notebook Materials

PAGES	MATERIAL	USE IN LESSON
OL – 1	Schematic Plan and Section of typical lagoon	Background for Subdivision 1
OL – 2	Seasonal Flow Patterns – Two Stage Lagoons	Reference by instructor Subdivision 1, Section III
OL – 3	References	


STREAM
CELL 1
CELL 2
WASTE
8-10'
1
3
1
3
25 TO 50'
3 to 5'
WASTE

SCHEMATIC PLAN AND SECTION OF TYPICAL WASTE STABILIZATION LAGOON



SUMMER (July, August, September)
1. Flow Pattern: Series
2. Depth: 5 ft

FALL (October, November, December)
1. Flow Pattern:
    Oct., Nov. – Series
    Dec. – Parallel
2. Depth: Lower to 2½ – 3 ft
3. Effluent Shut off (Dec.)

WINTER (January, February, March)
1. Flow Pattern: Parallel
2. Effluent: Off
    (Hold All Flow)

SPRING (April, May, June)
1. Flow Pattern:
    Apr., May – Parallel
    June – Series
2. Depth: 5 ft

SEASONAL SEQUENCING OF FLOW PATTERN IN TWO-STAGE WASTE STABILIZATION LAGOONS

REFERENCES – OXIDATION LAGOONS

URS Research Company. Procedures for Evaluating Performance of Wastewater Treatment Plants. U.S. Environmental Protection Agency.

O'Brien, W.J., R.E. McKinney, M.D. Turvey. Two Methods for Algae Removal from Oxidation Pond Effluents. Water and Sewage Works, March, 1973. pp 66-73.

New York State Health Department. Manual of Instruction of Sewage Plant Operators.

U.S. Public Health Service, Region VI. Waste Stabilization Lagoons Design, Construction and Operator Practices Among Missouri Basin States. January 21, 1960.

U.S. Environmental Protection Agency, Technology Transfer. Upgrading Lagoons. August, 1973.

Goswami, S.R., W. H. Busch. Three Stage Ponds Earn Plaudits. Water and Wastes Engineering, April, 1972. pp 40-43.

U.S. Environmental Protection Agency. Supplement to Federal Guidelines: Design, Operation and Maintenance of Wastewater Treatment Facilities, Wastewater Treatment Ponds. Technical Bulletin, EPA 430/9-70-011, March, 1974.

Division of Sanitary Engineering, South Dakota State Department of Health. Operation and Maintenance of Stabilization Ponds.

Matthew, F.L., Operation and Maintenance of Aerobic Stabilization Ponds. Water and Wastes Engineering, July, 1968. p 64.

Brinck, C. W. Operation and Maintenance of Sewage Lagoons. Water and Sewage Works, October, 1972.

Minnesota Pollution Control Agency. Stabilization Pond Operation and Maintenance Manual. 1975.

LESSON – LABORATORY PRACTICES

Instructor Overview of Lesson

Entry Level Behavior: Students will have had University training in Sanitary Engineering, waste treatment and/or related sciences or equivalent in experience and training. Some field experience in inspecting treatment plants, but none in operating waste treatment facilities, or in laboratory analyses.

As a prerequisite to this course, it is recommended that the student will be able to –

1. Identify treatment plant process units
2. Describe treatment plant process units and equipment in technical terms
3. Identify and explain the purpose of components of treatment plant process units, how they work and why they are important to the overall process
4. Describe the normal operating procedures for treatment plant process unit components
5. Identify when treatment plant process units are not operating properly

Instructor Objectives: The principal instructor objectives for this lesson are:

1. To have students be able to use the plant laboratory as a tool for troubleshooting and process control
2. To provide students with sources of information on using the laboratory for troubleshooting
3. To train students to recognize and evaluate factors of treatment plant laboratory adequacy, and to troubleshoot laboratory problems

References: Note list of references included with Student Notebook materials

Total Length of Lesson: 90 Minutes for 2 lesson subdivisions

LESSON OVERVIEW

Subdivision Title & Time	Major Student Objectives	Key Points & Content	Approach	Materials
1. The Laboratory as a Tool for Process Control and Troubleshooting	1. Describe lab uses for process control and troubleshooting 2. Utilize sampling procedures	1. Process of troubleshooting requires good lab analysis 2. Inadequate labs have caused poor process controls	1. Follow lesson outline, using slides and key 2. Encourage student discussion	1. Process of Troubleshooting Chart 2. Slide series and key
30 Minutes	3. Evaluate treatment	3. Troubleshooters need to know proper sampling procedures	3. Continually focus on the *value* of the lab for troubleshooting and process control	3. EPA Manual on Plant Evaluation 4. Student Notebook Materials drawn from EPA Manual on "Estimating . . ." 5. Student Notebook page Recommended Means of Preserving Samples, page LP-5
2. Troubleshooting Laboratory Practices	1. Identify and evaluate factors of lab adequacy	1. Three factors which indicate lab adequacy	1. Follow lesson outline, using slides and key, and Notebook materials	1. Slide series of word and picture slides, and slide key
	2. Evaluate lab staffing and procedures	2. Lab staff and procedures can be upgraded	2. Slide series should stress involvement of students in identifying the significance of what is seen on the slides	2. Student Notebook material drawn from EPA Manual on "Estimating . . ."
60 Minutes	3. Evaluate lab equipment, facilities and housekeeping	3. Lab housekeeping, maintenance and safety precautions are important indicators of lab adequacy		3. Student Notebook – Laboratory Equipment Troubleshooting Guide
	4. Identify and prevent safety hazards 5. Approach lab troubleshooting constructively to overcome barriers	4. Troubleshooter attitude and behavior is important toward overcoming troubleshooting barriers		
30 Minute Optional Section on lab Equipment	1. To identify commonly used laboratory equipment 2. To identify favorable and unfavorable lab conditions	1. Specific laboratory equipment	1. Use Slides and Slide Key – full discussion by students	1. Slide series of 24 slides, and key

LESSON – LABORATORY PRACTICES

Presentation Options for Course Director

The 90 minute lesson on LABORATORY PRACTICES is an important part of the overall troubleshooting approach being stressed throughout this course. The one hour, 30 minute time period is felt to be appropriate in relation to a total course effort of between 28 and 40 hours. If it is necessary to present this course in fewer than 28 hours then the Course Director should consider reducing this lesson in scope, or eliminating it altogether. If the course is expanded beyond 40 hours, there are several options for lengthening this lesson if desired.

The developers of the course believe that it would not normally be advisable to expand this lesson unless the students attending the course had a specific interest or need to better their familiarity with the laboratory. If not, it is felt that typical target students would more greatly benefit from expansions in other lessons. Any expansion of this lesson should include ample opportunity for *student participation*, inasmuch as the lesson as it now stands is primarily structured in a lecture-slide format, with less focus on student participation and involvement than some of the longer lessons. Options for presenting this lesson include:

Subdivision 1 – The Laboratory As a Tool for Process Control and Troubleshooting:

A section can be added to this subdivision on developing a systematic unit process testing program for a treatment plant laboratory. By using Chapter II and Appendix A of "Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities," examples of developing process testing programs can be performed by the instructor, or by the class in their designated student groups. If the need exists, and time permits, a period of up to 4 hours could be devoted to this activity. If this approach is to be used, the instructor will have to obtain and provide copies of the pertinent materials for the student's use.

Control Tests: If it is desired to familiarize the class with specific control tests, material from the National Waste Treatment Center, EPA Cincinnati can be utilized. These consist of material on control tests for the Activated Sludge Process prepared by A.W. West, Director of the National Waste Treatment Center. Materials available include: Manual – "Operational Control Procedures for the Activated Sludge Process – Part II, Control Tests," April 1973, and a slide-tape series, Control Tests, Part II, XT-41, 17 minutes. (Available at all EPA Regional Headquarters). A period of up to 2 hours may be spent reviewing control tests in the laboratory, in conjunction with the Laboratory Practices lesson or the Activated Sludge lesson.

Laboratory visit: If time is available, and the facilities are convenient, small groups may be taken on actual visits to wastewater treatment plant laboratories. This should only be done where a specific need exists to familiarize students with an actual working lab.

Subdivision 2 – Troubleshooting Laboratory Practices:

Section III, Troubleshooting Laboratory Facilities and Equipment, may be supplemented with a slide series showing commonly used laboratory equipment. Additional material is included in the lesson plan as Section V, Optional Section on Laboratory Equipment. If used, this option should be given 30 minutes, with plenty of time allowed for student discussion. A 24-slide series and key are provided with the lesson plan should this option be included by the Course Director.

LABORATORY PRACTICES

LESSON PLAN – SUBDIVISION 1 **TIME: 30 MINUTES**

Title: The Laboratory as a Tool for Process Control and Troubleshooting

Instructor Objectives: To have students be able to use the plant laboratory as a tool for troubleshooting plant operating problems, and for overall plant process control. To have students know where to locate additional information on using the laboratory for troubleshooting.

Student Objectives: As a result of this lesson subdivision, students will be able to do the following:

1. Describe the uses of the laboratory for process control, and in implementing the Process of Troubleshooting
2. Utilize sampling procedures to carry out troubleshooting activities
3. Evaluate treatment plant personnel and troubleshoot problems in sampling and sample handling

Training Materials:

This lesson subdivision requires numerous training materials, most of which are provided with the lesson plan. These include:

Process of Troubleshooting Chart

Slide series of 7 word slides, and slide key in lesson plan outline

Process control guides listed in outline, by West, and Hayes and Zickefoose

EPA Manual, "Evaluating the Performance of Wastewater Treatment Plants"

Student Notebook materials drawn from EPA Manual, "Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities," pp LP-1 thru LP-4

Student Notebook page LP-5, Recommended Means of Preserving Samples

Classroom Set-up:

A normal classroom set-up will be required. Students should be seated with their student groups

35 mm carousel slide projector with remote controls

Large screen (8 ft x 10 ft)

Chalkboard or easel

Pointer

Subdivision Schedule:

Within the 30 minute time period, the following schedule should be observed in presenting the lesson plan outline

TIME	SUBJECT
0 – 10 Minutes	Troubleshooting and Laboratory Practices
10 – 30 Minutes	Guide to Sampling

Subdivision Approach:

The instructor is to rely on the lesson outline, using the slide series and slide key. Student questions, comments and discussion are to be encouraged all throughout the lesson subdivision.

The instructor should make reference to and utilize Student Notebook materials prepared for this subdivision.

Throughout this subdivision, the instructor should focus on the *value* of the laboratory for troubleshooting and for process control. This is *not* to be a lesson in performing laboratory analyses, nor should it become a lesson in wastewater chemistry.

LESSON OUTLINE

I. Troubleshooting and Laboratory Practices (10 Minutes)

A. The Process of Troubleshooting

Use of a systematic troubleshooting process may be dependent on good lab capabilities, particularly for larger, more complex plants

1. "USING THE LAB IN THE PROCESS OF TROUBLESHOOTING"

Step le – Sample, test and analyze
Step lf – Process test and analyze
Step 4 – Observe and test
Step 5b – Monitor results

B. Process Controls

1. 1975 Survey of Federally Funded Wastewater Treatment Facilities showed –

   a. 20% of all secondary treatment plants are "marginal," meaning they can meet secondary treatment requirements with improved O&M

   b. In many plants, process controls are lacking because of inadequate operational data (primarily smaller plants)

   c. Inadequate operational data most frequently results from
      1. Inadequate lab facilities
      2. Inadequate sampling and testing programs

2. Most process control guides and methods depend upon lab analyses

Examples:

a. Al West – Operational Control Procedures for the Activated Sludge Process, Part II, Control Tests, EPA Cincinnati

KEY POINTS & INSTRUCTOR GUIDE

Key Point: Use of the Process of Troubleshooting requires good lab analysis in many situations.

Guide: Relate the Process of Troubleshooting to lab analyses by
1. Referring class to Troubleshooting Chart in Student Notebook, and
2. Using

SLIDE LP-1 (word)

These steps depend upon lab analysis.

Key Point: Inadequate labs have been found to be a major reason for inadequate process controls.

Refer students to paper on the Survey by W.G. Gilbert, listed in References, Student Notebook

Guide: Instructor should display process control guides if they are available.

These guides are all listed under the lesson References – Student Notebook.

b. Hayes & Zickefoose – Operator's Pocket Guide to Activated Sludge, Part II, Process Control and Troubleshooting

c. EPA Procedural Manual, "Evaluating the Performance of Wastewater Treatment Plants"

C. Uses of the Laboratory

1. The laboratory can be the "best friend" of the plant operator and troubleshooter

2. Plant operators and troubleshooters must know how to use the lab so that it gives the information they need

3. Lab users must be able to know if it is performing up to standard (covered in Subdivision 2 of this lesson).

4. The operator and troubleshooter must know how to distinguish between various uses of the lab

a. "REASONS FOR USING PLANT LAB"

- Performance Compliance Records
- Historical Interest
- Process Control
- To design plant improvements
- Cost data comparisons
- Troubleshooting operating problems

SLIDE LP-2 (word)

b. "RECORD VS CONTROL TESTING"

1. Record:
    a. To monitor past performance
    b. Officially recognized methods
    c. Acceptable long-term records
2. Control:
    a. To upgrade present performance
    b. Rapid tests of status now for corrective action
    c. Short term interest

SLIDE LP-3 (word)

Key Point: Laboratory requirements differ for different uses.

c. "PROCESS CONTROL INFORMATION"

Look-feel-smell
Temperature
Blanket depth
Settling rate
Conductivity
Turbidity
D.O.
Flow

SLIDE LP-4 (word)

LESSON OUTLINE

5. Points to stress
    - a. "Standard Methods" may be required for NPDES reporting, but
    - b. For process control testing and troubleshooting, analyses must be used which
        1. Can be performed quickly and easily
        2. Do not require 5 days in order to obtain results
        3. Give reasonable accuracy – however, extreme precision is not necessary as long as trends can be measured, and consistent results can be obtained

II. Guide to Sampling (20 Minutes)

- A. Sampling for Troubleshooting (5 Minutes)
    1. By knowing routine sampling requirements for process control, torubleshooter will be aware of an initial approach to sampling needed when operating problems occur
    2. Troubleshooters should be familiar with available guides:
        - a. EPA Manual, "Evaluating the Performance of Wastewater Treatment Plants," Table III-1, Process Testing Guide page 33. This guide provides information for each treatment process on the parameters to test for and the frequency of sampling
        - b. EPA Manual "Estimating Laboratory Needs . . ." Appendix A, pages A-1 thru A-29. These tables have useful process diagrams to show sampling points. Note: That while this manual is now out of print and thus can't be distributed, it has had wide distribution to state agencies and should be available to the students

KEY POINTS & INSTRUCTOR GUIDE

Guide: Four pages from Appendix A are included in the Student Notebook as sample pages.
LP-1 Primary Clarification
LP-2 Activated Sludge
LP-3 Secondary Clarifier
LP-4 Aerobic Digestion

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
3. Troubleshooters should try to isolate plant problems by analyzing records and trends from process testing for the entire plant, and then narrow the testing down to the actual problem areas	
4. Have plant lab personnel, if there are any, run process tests for specific processes in trouble, to analyze specific alternative courses of action	This approach is characterized in the following slide.
"SAMPLING FOR TROUBLESHOOTING" • Be familiar with routine sampling for process controls • Use EPA Manuals for reference • Isolate problems by analyzing plant records and trends • Run process tests in plant problem areas	SLIDE LP-5 (word)
B. Sampling Procedures and Sample Handling (10 Minutes)	
1. Troubleshooter must know proper sampling procedures in order to – a. Evaluate plant personnel performance in this area b. Recommend improvements to plant superintendent regarding sampling and laboratory techniques c. Supervise plant personnel at process testing d. Sample himself where necessary to troubleshoot operating problems	Key Point: Troubleshooters must know sampling procedures.
2. Sample Types – There are three (3) principal sample types	
"SAMPLE TYPES" Grab Sample – manually collected at single location and time Composite sample – combines two or more grab samples Flow Proportional Composite Sample – Grab speciments are in proportion to flow – most reliable	SLIDE LP-6 (word)

LESSON OUTLINE

a. Grab Sample

1. A grab sample is manually collected at a single location and moment in time. Information gained from the grab sample is truly representative of the stream sampled for only that moment in time

2. Individual testings of repetitive grab samples collected at frequent intervals over an extended period of time will yield valuable information concerning the variations and degree of variations of the water or waste chemical characteristics

3. Grab samples are ordinarily specified where the parameter to be analyzed is unstable and subject to rapid change (e.g., pH, bacteria, acidity)

b. Composite Sample

A composite sample may be obtained by combining two or more grab samples into a single specimen for analysis. Data derived from analysis of a composite sample is indicative of the average stream character. The reliability of the composite sample as an indicator of average character is increased in proportion to the increasing number of grab samples used in preparing the composite

c. Flow Proportioned Composite Sample

A composite sample obtained by combination of grab specimens in proportion to flow at time of individual grab specimen collection is known as a flow proportioned composite. Flow proportioned composite samples yield the most reliable data concerning average chemical characteristics over the sampling interval

KEY POINTS & INSTRUCTOR GUIDE

Guide: More detailed explanation of material on slide.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
3. Sampling Frequency and Location	
a. NPDES Permit Monitoring	
The NPDES permit for the wastewater treatment facility under evaluation will specify the location and frequency of sampling for applicable NPDES test parameters	
The inspector should assure that sampling personnel understand designated sampling frequency and location and are satisfying these permit conditions	
b. Process Control Sampling	
1. Process control sampling frequency and location is dependent upon plant size, types, degree of treatment provided, type and nature of industrial wastes received, and historic as well as existing plant performance	
2. The inspector may wish to perform an estimation of minimum and optimum sampling/testing needs for a particular plant prerequisite to his visitation by comparison with the estimated required program	
4. Sampling Technique and Equipment	
"SAMPLING TECHNIQUE AND EQUIPMENT"	SLIDE LP-7 (word)
• Samples must be representative • Sufficient volume for lab testing • Clean bottles and apparatus • Proper labeling and identification • Automatic devices must be inspected • Samples taken to lab without delay • Sterile bottles for bacterial testing	

LESSON OVERVIEW

a. Sampling should be performed in a manner which yields truly representative specimens free of perturbations and/or contaminating materials which may lead to erroneous conclusions. For example, effluent samples should not contain leaves or other floating materials, sediment scoured from channel bottom during sampling, etc . . . which would influence test results and present a misleading characterization of the effluent quality

b. Samples must be of sufficient volume to enable proper laboratory processing and testing

c. Sample collection apparatus and sample bottles should be clean to prevent contamination and possible test interferences. Plastic and glass containers are preferred to metal

d. Samples should be labeled properly to facilitate chemist's identification of sample location, collection time, date, and sampler

e. Automatic sampling devices should be inspected periodically to assure timer controls, refrigerator unit, or other critical components are in proper working order

f. Sample should be returned to laboratory without delay

g. Samples for bacteria testing should be collected manually using sterile bottles and aseptic technique. Samples should be obtained from at least 6 inches below the water surface. The bottle should not be filled to the top to enable proper mixing prior to testing

KEY POINTS & INSTRUCTOR GUIDE

Guide: More detailed explanation of material on slide.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
5. Preservation of Samples	
a. Samples to be analyzed for unstable test parameters should be treated with the appropriate preservation technique and in accordance with Environmental Protection Agency recommendations. (Table presented in Student Notebook)	Refer to Student Notebook page – Recommended Means of Preserving Samples. Page LP-5.
b. However, samples for process testing and troubleshooting should be analyzed immediately where possible	Review table with class only if there is interest in the details of preserving samples.
c. The inspector may refer to a detailed outline of approved sample preservatives, sample container materials, and sample holding times found in "Manual of Methods for Chemical Analysis of Water and Wastes," U.S. Environmental Protection Agency, (1974) pages vii-xii	
C. Sampling for Specific Treatment Processes (5 Minutes)	Guide: Use Student Notebook pages LP-1 thru LP-4 as references for this section.
1. Briefly run through Notebook pages LP-1 thru LP-4 to point out the variation in estimated process sampling and testing needs for each process	
2. Primary Clarification (page LP-1)	
a. Number of parameters – 6 suggested minimum, 2 optional	Key Point: In reviewing this material, students should become familiar with the estimated sampling and testing needs.
b. Frequency of sampling – from 3 times a day (sludge volume) to once a week (total solids)	
c. Location of sampling – 3 locations, influent, effluent, sludge underflow	
d. Method of sampling – 2 methods 24 hour composite, grab sample	

RECOMMENDED MEANS OF PRESERVING SAMPLES

PRESERVATIVE	ACTION	APPLICABLE TO
$HgCl_2$	Bacterial Inhibitor	Nitrogen forms Phosphorus forms
Acid (HNO_3)	Metals solvent, prevents precipitation	Metals
Acid (H_2SO_4)	Bacterial Inhibitor	Organic samples (COD, oil and grease, organic carbon)
	Salt formation with organic bases bases	Ammonia, amines
Alkali (NaOH)	Salt formation with volatile compounds	Cyanides, organic acids
Refrigeration	Bacterial Inhibitor	Acidity-alkalinity, organic materials, BOD, color, odor, organic phosphorus, organic nitrogen, biological organisms (coliforms, etc)

This table is provided in the Student Notebook as Page LP-5

LESSON OUTLINE

3. Activated Sludge (page LP-2)
    a. Number of parameters – 13 suggested minimum, 4 optional
    b. Frequency of sampling – From continuous (flow, air) to twice a week (BOD)
    c. Location of sampling – 5 locations, influent, effluent, process, blower, recycle sludge
    d. Method of sampling – 3 methods, 24 hour composite, grab sample, record continuously
4. Secondary Clarifier (page LP-3)
    a. Number of parameters – 11 suggested minimum, 3 optional
    b. Frequency of sampling – from continuous (flow) to once a week (total solids)
    c. Location of sampling – locations, influent, effluent, sludge underflow, waste sludge, recycle sludge
    d. Method of sampling – 4 methods, 24 hour composite, grab sample, record continuously, monitor continuously
5. Aerobic Digester (page LP-4)
    a. Number of parameters – 11 suggested minimum, 1 optional
    b. Frequency of sampling – from continuous to twice a week (total solids)
    c. Location of sampling – 5 locations, influent, digested sludge, supernatant, process blower
    d. Method of sampling – 2 methods, grab sample, record continuously

KEY POINTS & INSTRUCTOR GUIDE

LABORATORY PRACTICES

LESSON PLAN – SUBDIVISION 2 **TIME: 60 MINUTES**

Title: Troubleshooting Laboratory Practices

Instructor Objectives: To train students to recognize and evaluate factors of treatment plant laboratory adequacy, and to troubleshoot problems in laboratory practices.

Student Objectives: As a result of this lesson subdivision, students will be able to do the following:

1. Identify and evaluate the principal factors which indicate laboratory adequacy
2. Estimate the staffing needs for municipal wastewater treatment plant laboratories
3. Make recommendations for upgrading laboratory staff adequacy
4. Observe and evaluate laboratory procedures
5. Identify basic laboratory equipment and troubleshoot equipment problems
6. Recognize and evaluate the adequacy of laboratory facilities
7. Evaluate laboratory maintenance and housekeeping practices
8. Identify laboratory safety hazards
9. Recommend measures to prevent or safeguard against laboratory safety hazards
10. Recognize the barriers to troubleshooting laboratory problems and approach troubleshooting with a constructive attitude using a Systematic Process of Troubleshoooting

Training Materials:

Slide series of 6 word slides and 19 picture slides, and slide key in lesson outline

Student Notebook, Nomographs of lab staff reproduced from EPA Manual "Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities," pages LP-6 and LP-7

Student Notebook – Laboratory Equipment Troubleshooting Guide, pages LP-8 to LP-13

Student Notebook, Nomographs on Lab Floor Space, Bench Area and Cabinet Volume, reproduced from EPA Manual "Estimating . . . . .," pages LP-14 to LP-16

Optional: Slide series of 24 slides, and key, for optional section on laboratory equipment

Classroom Set-up:

A normal classroom set-up will be required. Students should be seated with their student groups

35 mm carousel slide projector with remote controls

Large screen (8 ft x 10 ft)

Chalkboard or easel

Pointer

Subdivision Schedule:

Within the 60 minute time period, the following schedule should be observed in presenting the lesson plan outline

TIME	SUBJECT
0 – 5 Minutes	Indicators of Laboratory Adequacy
5 – 20 Minutes	Troubleshooting Staff Deficiencies and Procedures
20 – 50 Minutes	Troubleshooting Laboratory Facilities and Equipment
50 – 60 Minutes	Troubleshooting Laboratory Problems
60 – 90 Minutes	Optional Section on Laboratory Equipment

Subdivision Approach:

The instructor is to rely upon the lesson outline, using the slide series and slide key, and Notebook materials. The instructor should provide opportunities for student discussion.

The approach to Section III D, Laboratory Maintenance and Housekeeping, is particularly important. There is a series of 19 picutre slides showing good and bad maintenance and safety practices. These slides are most effective when the instructor allows the students to tell what is right or wrong with each picture. This slide series provides the best opportunity in the lesson for *student involvement*, and *it should be used for that purpose.* If the reaction to each slide by the class is not spontaneous, the instructor should call on a different student to describe what he sees in each slide that is shown.

Section V is a 30 minute optional section featuring slides on laboratory equipment. The Course Director should determine whether or not to use this section depending upon the background of the students and the objectives established for the course presentation. If this section is presented, student participation should be stressed.

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

I. Indicators of Laboratory Adequacy (5 Minutes)

There are three (3) principal factors around which the troubleshooter can evaluate laboratory adequacy

"EVALUATING LABORATORY ADEQUACY PRINCIPAL FACTORS"

- Staff composition and procedures
- Physical facilities and equipment
- Laboratory test results

SLIDE LP-8 (word)
Guide: Note that these are indicators for troubleshooters to look at.

A. "EVALUATING LABORATORY STAFF COMPOSITION AND PROCEDURES"

- Number and training of staff
- Handling of samples, data and equipment
- Existence of quality control procedures
- Ability to perform NPDES testing
- Procedures for process control testing
- Assistance provided to troubleshooters

SLIDE LP-9 (word)

B. "EVALUATING LABORATORY FACILITIES AND EQUIPMENT"

- Adequacy of equipment and facilities for the job to be done
- Cleanliness and overall housekeeping
- Maintenance of equipment and facilities
- Degree of down-time
- Attention to safety hazards, and safety precautions

SLIDE LP-10 (word)

C. "EVALUATING LABORATORY TEST RESULTS"

- Incomplete data and records
- Inconsistent results
- Signs of inaccuracy
- Evidence of quality controls
- "Dry Labbing" – pencil chemists

SLIDE LP-11 (word)

II. Troubleshooting Staff Deficiencies and Procedures (15 minutes)

A. Adequacy of Lab Staff (5 minutes)

1. Staffing needs – can be estimated by using nomograph found in EPA Manual "Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities."

References: Student Notebook, Figures from EPA Manual "Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities" Notebook Pages LP-6 and LP-7.

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

a. The staffing guidelines were developed from information gathered at wastewater treatment facilities throughout the country. The procedure may be used by the troubleshooter to confirm suspected staff inadequacy and in supporting his recommendation for increased lab personnel.

2. Personnel Qualifications

a. A well-trained lab staff lends itself to more efficient operation of the laboratory. Certification of lab workers is one way of insuring a capable staff. Lab personnel lacking in experience or proper training detract from the laboratory operation.

b. However, troubleshooter will rarely be capable of fairly judging personnel qualifications, nor will he usually have the opportunity.

3. Upgrading staff adequacy

Key Point: Troubleshooter plays an indirect role in upgrading plant laboratories.

In most instances the troubleshooter's role is necessarily limited to explaining the problem of staff inadequacy to the appropriate municipal officials. The troubleshooter may, however, be able to recommend one or more options available for resolving the problem.

"OPTIONS FOR UPGRADING LAB STAFF"

SLIDE LP-12 (word)

- Increase staff number
- Rearrange sampling/testing duties
- Eliminate or reduce unnecessary testing
- Increase supervision by qualified staff
- Upgrade equipment to reduce testing times
- Formal or on-site training
- Sub-contract difficult tests

B. Evaluating Laboratory Procedures (10 Minutes)

1. "PROCEDURES TO BE OBSERVED AND EVALUATED"

SLIDE LP-13 (word)

LESSON OUTLINE

- Sampling technique
- Approved test procedures
- Quality control
- Record keeping and reporting

Any of the above factors could be responsible for faulty and invalid laboratory results.

2. Sampling Technique
   a. Already discussed under Subdivision 1
   b. References should be used if questions arise
   c. If troubleshooter observes or suspects invalid sampling, he should work with chemist and plant operator in advising how to upgrade
3. Use of Approved Test Procedures
   a. Make sure chemist and operator are aware of proper testing procedures
   b. Lab adequacy is a factor – valid tests cannot be run using inadequate equipment
   c. Prescribed tests must be run
      1. "Federal Register" prescribed tests for NPDES
      2. "Standard Methods" where applicable
      3. Consistent and valid process control tests, even when "quick and dirty" methods are used
   d. Testing can be upgraded by
      1. Lab staff training
      2. Developing systematic testing program
      3. Some outside contracting, if lab is inadequate or staff is overworked or incapable
   e. Test kits have serious shortcomings
      1. Useful for field operations, some stream sampling
      2. Invalid for NPDES and process control testing
      3. Used in many low budget labs

KEY POINTS & INSTRUCTOR GUIDE

Key Point: Problems with test kits include:
accuracy
consistency
conformity with accepted test results

LESSON OUTLINE

4. Quality Control and Validation
   a. Lab chemist should establish quality control program, to
      1. Monitor reliability or reported data
      2. Meet program requirements for reliability
   b. Troubleshooters role
      1. Should determine if quality control program exists
      2. Can't be expected to know how to recommend improvements
      3. Refer problems to qualified experts
5. Record Keeping and Reporting
   a. Forms and bench sheets
      1. Should be standardized, and designed to fit the needs of the lab
      2. Should be maintained according to NPDES required 3-year interval
      3. Data should be transposed to a more permanent log
   b. NPDES Reporting
      1. Should observe criteria specified in permit
      2. Plant evaluator and troubleshooter should inspect file to see if reports are being properly completed
   c. Storage and Retrieval of Data
      1. Easily located permanent log should be used
      2. Log should be permanently bound
      3. Log should be validated by plant chemist after data is transposed

III. Troubleshooting Laboratory Facilities and Equipment (30 Minutes)
   A. Equipment (5 Minutes)
      1. Troubleshooter need not be an expert on laboratory equipment, but should know –
         a. Basic equipment needs
         b. When equipment is properly mounted, installed and maintained

KEY POINTS & INSTRUCTOR GUIDE

Key Point: Again stress the indirect role of the troubleshooter.

LESSON OUTLINE

2. Basic reference on equipment – Chapter III, EPA Manual, "Estimating Labloratory Needs for Municipal Wastewater Treatment Facilities" – Appendix B
3. Basic equipment and troubleshooting signs

Refer to pages in Student Notebook on Laboratory Equipment Troubleshooting. However, do not review this material. Have students review on their own, and keep for reference.

B. Physical Facilities (3 Minutes)

1. Inadequate physical facilities can lead to
   a. Reduction in lab efficiency
   b. Reduction in testing capability
   c. Reduction in staff morale
   d. Higher frequency of laboratory accidents
   e. Excessive breakage of glassware
2. Adequacy evaluated through nomographs presented in EPA Manual, "Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities"

   Nomographs reproduced in Student Notebook on –
   a. Floor space requirements
   b. bench area requirements
   c. storage cabinet requirements

C. Necessary Chemicals and Supplies (2 Minutes)

1. The troubleshooter will have little reason to review laboratory stock of chemicals and miscellaneous supply items. However, should inefficient laboratory work appear to be due to inadequate supply of chemicals, he may wish to take a closer look at chemical reagent stock and inventory practices.

KEY POINTS & INSTRUCTOR GUIDE

Reference: Student Notebook section – Laboratory Equipment Troubleshooting – a guide to troubleshooting 19 pieces of lab equipment. Notebook pages LP-8 thru 13.

Also: As an optional element to this course, slides of common types of lab equipment are available if it is desired that this part of the lesson be expanded.

Guide: Refer students to nomographs in Notebook, but do not take class time to review or use the nomographs in detail. Notebook pages LP-14 thru LP-16.

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

2. Listing of needed chemicals may be found in EPA Manual, "Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities."

D. Laboratory Maintenance and Housekeeping (10 Minutes)

Perhaps the best indication of probable inefficient laboratory operations and/or poor data quality is the appearance of the laboratory surroundings. A dirty or cluttered laboratory may reflect an improper attitude of the staff towards their testing responsibilities and similar lack of concern for good analytical technique.

1. Good laboratory housekeeping minimizes common lab accidents, reduces risk of sample contamination, improves the efficiency of the staff, and creates a pleasant environment leading to better staff morale.
   a. Floors and aisles are clear of obstructions and clean

      Spillages of chemicals and water are promptly attended to in order to prevent accidents
   b. Windows and lighting fixtures are clean in order to facilitate reading of analytical glassware and meters
   c. Dirty glassware is washed as frequently as necessary to provide readily available stock for testing demands
   d. The troubleshooter should recommend improved housekeeping in the laboratory should he feel it will benefit the operation
2. Laboratory maintenance should include periodic inspection of exhaust systems, water, gas, and electrical services, lighting, and drains

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
a. Failure of laboratory drain systems due to chemical attack may require substantial time for repair. Unless scheduled, such failures and repairs may affect prolonged periods of laboratory downtime	
b. Periodic inspection of laboratory wiring systems may prevent serious damage to the lab facility. The inherent nature of the chemicals found in the laboratory dictate all possible fire hazards should be monitored and corrected as indicated	
3. Visual observations are valuable in determining the quality of laboratory maintenance and management Show the following slides:	Guide: Use the following picture slide series to show the "do's" and "don'ts" of laboratory housekeeping. Slides should be shown in rapid sequence. *Class should be asked to comment and to point out problems portrayed by the slides.* Instructor should use this slide series as an opportunity for student involvement in the lesson.
SLIDE KEY	Guide: Seek comment from class on these slides.
a. Example of poor facilities 1. Lab and maintenance areas combined – grease? 2. Poor location of lab equipment	SLIDE LP-14
b. Poor facilities 1. Absorbent, dirty bench top 2. Poor storage practices 3. Floor and walls dirty and cluttered 4. Inadequate sink – dirty glassware?	SLIDE LP-15
c. Poor facilities 1. Inadequate sink and utilities – only cold water? 2. Inadequate lighting 3. Is phosphorus-free soap used for cleaning glassware for phosphorus testing – what will acid do to this sink?	SLIDE LP-16

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
d. Poor facilities? Get opinion from class as to what is wrong, if anything	SLIDE LP-17
e. Good facilities Adequate flow space and bench space, good maintenance	SLIDE LP-18
f. Good facilities with lab desk area Equipment neatly arranged	SLIDE LP-19
g. Balance Table and related equipment Is this table appropriate for the use?	SLIDE LP-20
h. Poor utilization of bench space 1. Note food preparation 2. Note chemicals next to food materials – poison?	SLIDE LP-21 Ask students to comment on problems.
i. Good utilization of limited bench space 1. Note consolidation of distillation/reflux activities 2. general neatness implies concern for testing duties	SLIDE LP-22 Question: Is the proximity to the window a problem?
j. Bottleneck due to buildup of dirty glassware 1. Why are dirty glassware items here? 2. Note lab has consolidated its titration activities and even provided white surface for better detection of colorimetric endpoints	SLIDE LP-23
E. Laboratory Safety (10 Minutes)	
1. The inherent potential for danger in the laboratory is great, due to use of toxic, volatile, and combustible chemicals, use of open flame, and quantity of exposed glassware. Some personal health risk is present due to the nature of samples being tested. The inspector should be prepared to note inadequacies in laboratory safety and make appropriate recommendations, although he should be aware that the actual authority for safety requirements is with OSHA, U.S. Department of Labor.	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
2. Laboratories should be equipped with proper safety equipment, including —	
SLIDE KEY	Guide: Use the following slides to discuss lab safety.
a. Fume Hood Best located near area of highest testing activity Additional exhaust systems may be needed where excessive heat, chemical vapors or noxious fumes are generated. Areas to be hooded are found near autoclaves, furnaces, locations for bacteria testing, etc.	SLIDE PL-24
b. Fire extinguishers of proper type, mounted in convenient locations and in accordance to code, and bearing tags certifying regular service.	SLIDE LP-25
c. Eye wash facilities available. May be hand held, economical wall mounted units, or fixture type.	SLIDE LP-26
d. Emergency shower is available and not used for storage.	SLIDE LP-27
3. Other safety precautions should include:	Key Point: The instructor should relate lab safety to an approach discussed in the lesson on Management Behavior — that of Management Systems. Does the lab (being inspected) have an organized safety program? Is there a management system for safety?
e. Fire blanket available to supplement emergency shower or in lieu of shower.	
f. Laboratory aprons, smocks, coats, rubber and asbestos gloves, eye goggles are available to staff and used where indicated.	
g. First aid station available at convenient location in laboratory.	
h. Facilities for quick mop-up of chemical spills are available (e.g., sand-soda ash buckets, etc.)	
i. Shields available and used in front of distillation glassware.	
4. Some laboratory safety hazards for troubleshooter to be aware of	Guide: Use slides to illustrate safety program.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
SLIDE KEY	
a. Improper storage of acids/alkali chemicals 1. Note sink drain will require repairs soon 2. Note corrosion of cabinet floors due to water and acid spillages – lack of concern?	SLIDE LP-28
b. Poor storage and use of shelf 1. Note shelf does not have restraining lip 2. Note acid bottles (glass) and heavy water carboys on poorly fabricated/supported shelf 3. Acids should be stored at floor level for safety	SLIDE LP-29
c. Overloaded electrical outlet and extension cord	SLIDE LP-30
d. Failure to use fume hood for potentially hazardous tests	SLIDE LP-31
e. Poor pipeting technique 1. Note concentrated sulfuric acid being pipeted by mouth 2. Where is worker's protective clothing? 3. What would you guess as skill level of this worker? How about his supervisor?	SLIDE LP-32

END OF SLIDE SERIES

Note that slides were taken at laboratory of treatment plant at Perrysburg, Ohio, which is a 2.74 MGD Activated Sludge Plant serving 8,000 people in northwest Ohio. This plant is unusual in that the superintendent is a skilled laboratory chemist and operator, and for several years ran a commercial analytical laboratory. The slides showing good conditions were actual, whereas the slides showing poor conditions were staged.

LESSON OUTLINE

IV. Troubleshooting Laboratory Problems (10 Minutes)

A. Laboratory Test Results

It is possible that treatment process performance, and overall plant efficiency are lower than design levels because the laboratory is providing inaccurate or misleading test data.

1. While possible, this is unlikely because plants which are well enough run to rely on lab tests for process controls are likely to have adequate laboratories.
2. If lab test results are suspect, parallel tests using outside laboratories should be run in order to validate lab results.
3. Troubleshooters can look for the following indicators of possible deficient lab results.
    - a. Incomplete data and records
    - b. Inconsistent results
    - c. Signs of inaccuracy – poor lab equipment use and procedures, etc
    - d. Evidence of quality controls
    - e. "Dry labbing"
4. Generally, lab results will be good if the lab –
    - a. Is adequately staffed with properly trained personnel
    - b. Utilizes standard and consistent procedures
    - c. Has adequate bench and floor space
    - d. Utilizes basic laboratory equipment, properly maintained
    - e. Shows evidence of good housekeeping and maintenance

B. Barriers for Troubleshooters to Overcome in Upgrading Laboratory Adequacy

1. It's easier to isolate problems than to recommend workable solutions

KEY POINTS & INSTRUCTOR GUIDE

Key Point: Keen observations are an important part of the Process of Troubleshooting.

Guide: Stress the importance of troubleshooter attitude and behavior in helping plant superintendants solve problems.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
2. Troubleshooter cannot enforce corrective action, he must be a convincing "salesperson."	
3. Must be able to document problems and justify recommendations	
4. Must present alternatives where possible, and stress possible benefits to the municipality	Stress the Systematic Process of Troubleshooting
5. Troubleshooter may expect to encounter the following attitude barriers	
a. Administration reluctant to appropriate funds for upgrading laboratory operations — a budget account historically regarded as nonessential to the treatment plant operation	
b. Resentment of lab staff to implications of technical inadequacy or incompetence	
c. Reluctance of plant operators to assume new or additional sample collection or testing responsibilities often regarded by them as "part of the chemist's job."	
C. Questions and discussion	Utilize any remaining time for class discussion.

LESSON OUTLINE

V. Optional Section on Laboratory Equipment (30 Minutes)

(See Lesson Introduction – Presentation Options for Course Director)

- A. Objectives of Optional Section
  1. To familiarize students with commonly used equipment in wastewater treatment plant laboratories
  2. To show favorable and unfavorable conditions for the use of lab equipment
  3. To allow students to participate fully
- B. SLIDE KEY
  1. Analytical Balance (mechanical model)
     - a. Poorly located, no knee space
     - b. Balance doors left open
     - c. Weights left on pan
     - d. Apparent lack of regard for precision instrument
  2. Analytical Balance (electrical model)
     - a. Properly located, clean
     - b. Related equipment nearby (e.g., desiccator)
  3. Trip Balance
     - a. Technician weighing directly on pan could result in corrosion
  4. pH Meter
     - a. Preferred condition
  5. pH Meter
     - a. Obvious meter not being used
     - b. Electrode not immersed in water and is in apparent poor condition
     - c. Absence of buffer solutions – faulty calibration?

KEY POINTS & INSTRUCTOR GUIDE

Guide: If this slide series is used, ample opportunity for student discussion and involvement should be provided.

Guide: This section should be presented only by persons familiar with the lab equipment being shown.

SLIDE LP-101

SLIDE LP-102

SLIDE LP-103

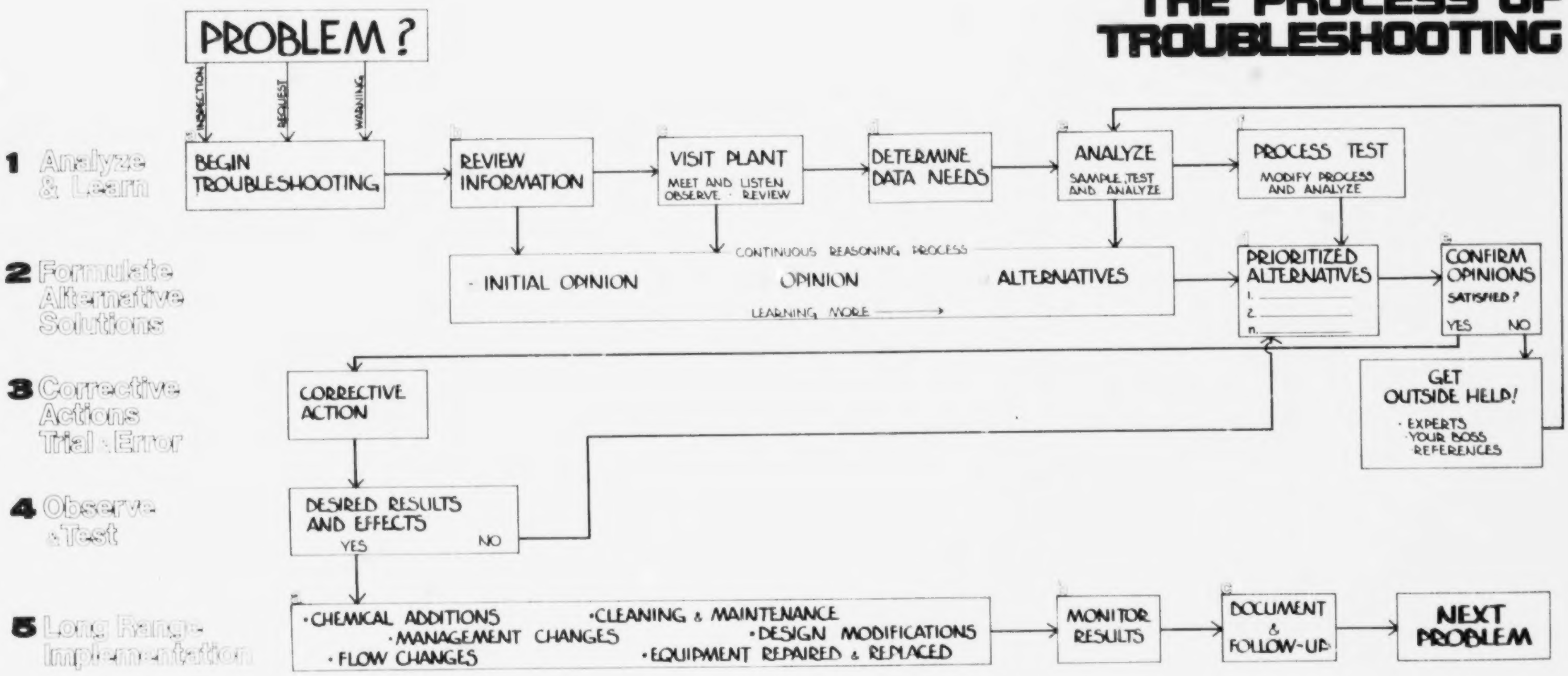
SLIDE LP-104

SLIDE LP-105

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
6. pH Meter a. Meter appears to be satisfactory b. Buffer solutions in open beaker and appear to be contaminated with algal growth	SLIDE LP-106
7. Drying Oven a. Top used for storage of broken glassware – danger! b. Volatile chemicals stored on oven top? c. Top-mounted thermometer not visible	SLIDE LP-107
8. Dry Oven Interior a. Contents oven located so as to prevent contamination in event of spillages? b. Crucibles and glassware appear to be properly marked to prevent mixup of specimens	SLIDE LP-108
9. Electric Muffle Furnace a. No exhaust system	SLIDE LP-109
10. Desiccator (glass model) a. Lid is broken and is not matched to base – poor seal? b. Particles of indicator desiccant material (blue) are mixed with non-indicating type. Blue color shows desiccant is still active	SLIDE LP-110
11. Desiccator (cabinet model) a. Desiccant material is exhausted (pink color)	SLIDE LP-111
12. BOD Incubator a. Preferred organization of contents and clean chamber b. BOD bottles do not have top covers – is water seal still present or has it evaporated?	SLIDE LP-112
13. Water Still (glass model) a. Preferred condition	SLIDE LP-113

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
14. Water Still (glass model) a. preferred condition	SLIDE LP-114
15. Deionizer System a. Preferred condition – note indicator system built into exchange medium to warn of loss of exchange ability	SLIDE LP-115
16. Colorimeter a. Preferred condition – note related items nearby. Timer indicates chemist does monitor color development times	SLIDE LP-116
17. Spectrophotometer a. Preferred condition – note related items nearby including operating instructions	SLIDE LP-117
18. Refrigerator a. Poor use of refrigerator – food next to waste specimens b. What kind of chemicals are stored here? c. Needs defrosting	SLIDE LP-118
19. Autoclave a. Preferred condition – note contents wrapped	SLIDE LP-119
20. Electric Hotplates and Heating Mantle (upper right corner) a. Preferred condition b. Note safety goggles near distillation units	SLIDE LP-120
21. Dissolved Oxygen Analyzer a. Preferred condition – related items nearby	SLIDE LP-121
22. Water Bath Incubator a. Lid not properly placed on both – evaporation? b. Thermometer is missing from bath	SLIDE LP-122
23. Total Organic Carbon Analyzer a. Preferred condition	SLIDE LP-123
24. Atomic Absorption – Emission Spectrophotometer a. Preferred condition – related gas cylinders in background should be checked for proper support	SLIDE LP-124

THE PROCESS OF TROUBLESHOOTING


1 Analyze & Learn
2 Formulate Alternative Solutions
3 Corrective Actions Trial & Error
4 Observe & Test
5 Long Range Implementation
PROBLEM?
INSPECTION
REQUEST
WARNING
BEGIN TROUBLESHOOTING
REVIEW INFORMATION
VISIT PLANT
MEET AND LISTEN
OBSERVE · REVIEW
DETERMINE DATA NEEDS
ANALYZE
SAMPLE, TEST AND ANALYZE
PROCESS TEST
MODIFY PROCESS AND ANALYZE
CONTINUOUS REASONING PROCESS
· INITIAL OPINION
OPINION
ALTERNATIVES
LEARNING MORE
PRIORITIZED ALTERNATIVES
1.
2.
n.
CONFIRM OPINIONS
SATISFIED?
YES
NO
GET OUTSIDE HELP!
· EXPERTS
· YOUR BOSS
· REFERENCES
CORRECTIVE ACTION
DESIRED RESULTS AND EFFECTS
YES
NO
· CHEMICAL ADDITIONS
· CLEANING & MAINTENANCE
· MANAGEMENT CHANGES
· DESIGN MODIFICATIONS
· FLOW CHANGES
· EQUIPMENT REPAIRED & REPLACED
MONITOR RESULTS
DOCUMENT & FOLLOW-UP
NEXT PROBLEM

LP 2-18

STUDENT NOTEBOOK MATERIALS

The following materials are included in the section of the Student Notebook on Laboratory Practices. The Notebook is distributed to students at the start of the course, and is available to them as a reference material throughout the course. Some of these materials are to be used by the instructor as an integral part of the lesson.

Index of Notebook Materials

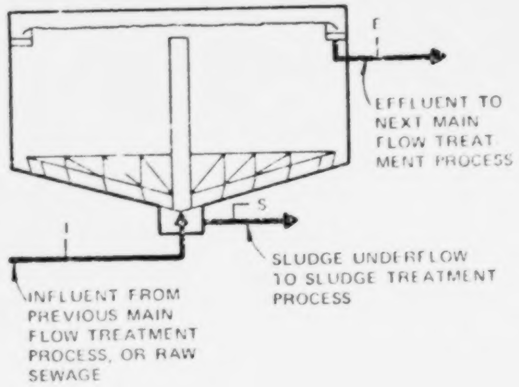
PAGE	MATERIAL	USE IN LESSON
LP – 1 thru 4	Estimated Unit Process Sampling and Testing Needs, Appendix A*	Reference by Instructor, Subdivision 1, Section II These pages are used in the presentation of Section II C
LP – 5	Recommended Means of Preserving Samples	Reference by Instructor Subdivision 1, Section II
LP – 6 and 7	Manpower Estimate Charts, Appendix D*	Reference by Instructor Subdivision 2, Section II
LP – 8 thru 13	Laboratory Equipment Troubleshooting	Reference by Instructor Subdivision 2, Section III
LP – 14 thru 16	Estimated Floor Space, Bench Area and Cabinet Volume, Appendix C*	Reference by Instructor Subdivision 2, Section III
LP – 17	References	

* Denotes materials reproduced from EPA Manual, "Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities"

ESTIMATED UNIT PROCESS SAMPLING AND TESTING NEEDS

PRIMARY CLARIFICATION

		PLANT SIZE (MGD)	TEST FREQUENCY	LOCATION OF SAMPLE	METHOD OF SAMPLE	REASON FOR TEST
SUGGESTED MINIMUM	BOD	ALL	2/W	I E	24C	H
	SUSPENDED SOLIDS	ALL	3/W	I E	24C	H
	SETTLEABLE SOLIDS	ALL	3/W	I E	G	H
	TOTAL SOLIDS	<1	3/W	S	G	P
	SLUDGE VOLUME LAB CENTRIFUGE	>1	3/D	S	G	P
	TOTAL SOLIDS	>1	1/W	S	G	P
OPTIONAL	COD	>15	1/W	I E	24C	H
	VOLATILE SUSPENDED SOLIDS	>5	3/W	I E	24C	H


E
EFFLUENT TO NEXT MAIN FLOW TREATMENT PROCESS
S
I
SLUDGE UNDERFLOW TO SLUDGE TREATMENT PROCESS
INFLUENT FROM PREVIOUS MAIN FLOW TREATMENT PROCESS, OR RAW SEWAGE

A. TEST FREQUENCY

H = HOUR
D = DAY
W = WEEK
M = MONTH
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

B. LOCATION OF SAMPLE

I = INFLUENT
E = EFFLUENT
S = SLUDGE UNDERFLOW

C. METHOD OF SAMPLE

24C = 24 HOUR COMPOSITE
G = GRAB SAMPLE
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

D. REASON FOR TEST

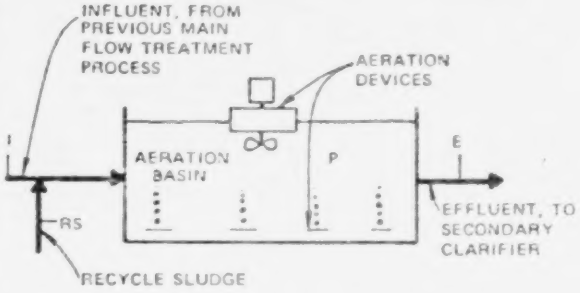
H = HISTORICAL KNOWLEDGE
P = PROCESS CONTROL
C = COST CONTROL

E. FOOTNOTES:

ESTIMATED UNIT PROCESS SAMPLING AND TESTING NEEDS

SECONDARY TREATMENT

ACTIVATED SLUDGE


INFLUENT, FROM PREVIOUS MAIN FLOW TREATMENT PROCESS
AERATION DEVICES
I
AERATION BASIN
P
E
RS
EFFLUENT, TO SECONDARY CLARIFIER
RECYCLE SLUDGE

		PLANT SIZE (MGD)	TEST FREQUENCY	LOCATION OF SAMPLE	METHOD OF SAMPLE	REASON FOR TEST
SUGGESTED MINIMUM	BOD	ALL	2/W	I	24C	P
	SUSPENDED SOLIDS	ALL	5/W	E	24C	P
	SETTLEABILITY	ALL	5/W	E	G	P
	pH	ALL	5/W	P	G	P
	DO	ALL	5/W	P	G	P
	AIR INPUT(1)	ALL	R	B	R	H
	NH_3-N(2)	ALL	1/D	I(3)	24C	H
	ORG-N(2)	ALL	1/D	I(3)	24C	H
	NO_3-N(2)	ALL	1/D	I(3)	24C	H
	TOTAL-P(2)	ALL	3/W	I(3)	24C	H
	ORTHO-P(2)	ALL	3/W	I(3)	24C	H
	FLOW	ALL	R	RS	R	P
	MICROSOPIC ANALYSIS	ALL	2/W	P	G	H
OPTIONAL	NO_3-N	ALL	3/W	P	G	P
	TOTAL SOLIDS	>1	3/W	E	24C	H
	TOTAL VOLATILE SOLIDS	>1	3/W	E	24C	H
	COD	>5	2/W	I	24C	H

A. TEST FREQUENCY

H = HOUR
D = DAY
W = WEEK
M = MONTH
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

B. LOCATION OF SAMPLE

I = INFLUENT
E = EFFLUENT
P = PROCESS
B = BLOWER (INCLUDE WITH PROCESS TESTING)
RS= RECYCLE SLUDGE

C. METHOD OF SAMPLE

24C = 24 HOUR COMPOSITE
G = GRAB SAMPLE
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

D. REASON FOR TEST

H = HISTORICAL KNOWLEDGE
P = PROCESS CONTROL
C = COST CONTROL

E. FOOTNOTES:

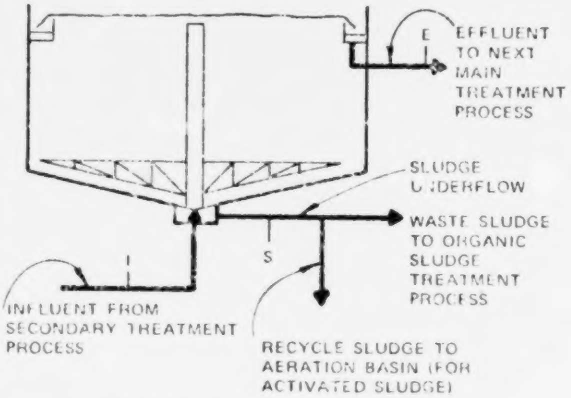
1. DIFFUSED AIR ONLY
2. TO BE RUN IF PROCESS IS DESIGNED TO CONTROL THIS PARAMETER
3. MAYBE RUN ON PLANT INFLUENT IF THIS IS INITIAL UNIT PROCESS FOLLOWING PRETREATMENT.

ESTIMATED UNIT PROCESS SAMPLING AND TESTING NEEDS

SECONDARY TREATMENT

		PLANT SIZE (MGD)	TEST FREQUENCY	LOCATION OF SAMPLE	METHOD OF SAMPLE	REASON FOR TEST
SUGGESTED MINIMUM	SUSPENDED SOLIDS	ALL	3/W	I E	24C	P
	BOD	ALL	2/W	E	24C	H
	SETTLEABLE SOLIDS	ALL	1/D	I E	G	P
	TOTAL SOLIDS	<1	3/W	S	G	P
	NH_3-N(1)	ALL	1/D	E	24C	H
	ORG-N(1)	ALL	1/W	E	24C	H
	NO_3-N(1)	ALL	1/D	E	24C	H
	TOTAL-P(1)	ALL	1/D	E	24C	H
	ORTHO-P(1)	ALL	1/D	E	24C	H
	FLOW	ALL	R	WS RS	R	P
	SLUDGE VOLUME LAB CENTRIFUGE	>1	3/D	S	G	P
	TOTAL SOLIDS	>1	1/W	S	G	P
OPTIONAL	ALKALINITY	ALL	1/W	1	24C	P
	pH	ALL	1/D	1	G	H
	TURBIDITY	>15	Mn	E	Mn	P

SECONDARY CLARIFIER


E
EFFLUENT TO NEXT MAIN TREATMENT PROCESS
SLUDGE UNDERFLOW
WASTE SLUDGE TO ORGANIC SLUDGE TREATMENT PROCESS
S
I
INFLUENT FROM SECONDARY TREATMENT PROCESS
RECYCLE SLUDGE TO AERATION BASIN (FOR ACTIVATED SLUDGE)

A. TEST FREQUENCY

H = HOUR
D = DAY
W = WEEK
M = MONTH
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

B. LOCATION OF SAMPLE

I = INFLUENT
E = EFFLUENT
S = SLUDGE UNDERFLOW
WS = WASTE SLUDGE
RS = RECYCLE SLUDGE

C. METHOD OF SAMPLE

24C = 24 HOUR COMPOSITE
G = GRAB SAMPLE
R = RECORD CONTINUOUSLY
Mn = MONITOR CONTINUOUSLY

D. REASON FOR TEST

H = HISTORICAL KNOWLEDGE
P = PROCESS CONTROL
C = COST CONTROL

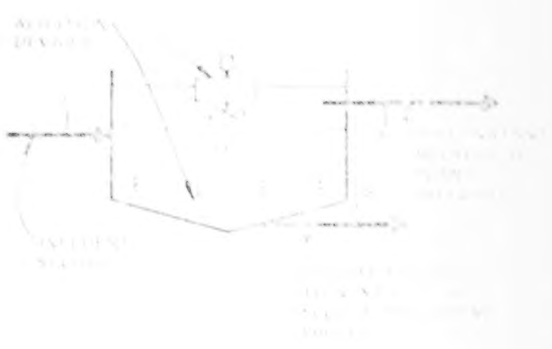
E. FOOTNOTES:

1. TO BE RUN IF PROCESS IS DESIGNED TO CONTROL THIS PARAMETER.

ESTIMATED UNIT PROCESS SAMPLING AND TESTING NEEDS

SOLIDS REDUCTION

AEROBIC DIGESTION



		PLANT SIZE MGD	TEST FREQUENCY	LOCATION OF SAMPLE	METHOD OF SAMPLE	REASON FOR TEST
SUGGESTED MINIMUM	TEMPERATURE	ALL	1/D	P	G	H
	pH	ALL	1/D	P	G	H
	TOTAL SOLIDS	ALL	2/W	I DS	G	H
	TOTAL VOLATILE SOLIDS	ALL	2/W	I DS	G	H
	DO	ALL	1/D	P	G	P
	AIR INPUT[1]	ALL	H	B	M	P C
	SETTLEABLE SOLIDS	ALL	2/W	P	G	H
	FLOW	ALL	R	DS	R	P
	pH	ALL	(2)	S	G	H
	SUSPENDED SOLIDS	ALL	(2)	S	G	H
	BOD	ALL	(2)	S	G	P[3]
	FLOW	ALL	R	S	R	P[3]
OPTIONAL	ALKALINITY	ALL	2/W	P	G	H

A. TEST FREQUENCY
H — HOUR M — MONTH
D — DAY [illegible]
W — WEEK [illegible]

B. LOCATION OF SAMPLE
I — INFLUENT
DS — [illegible]
S — SUPERNATANT
P — [illegible]
B — [illegible]

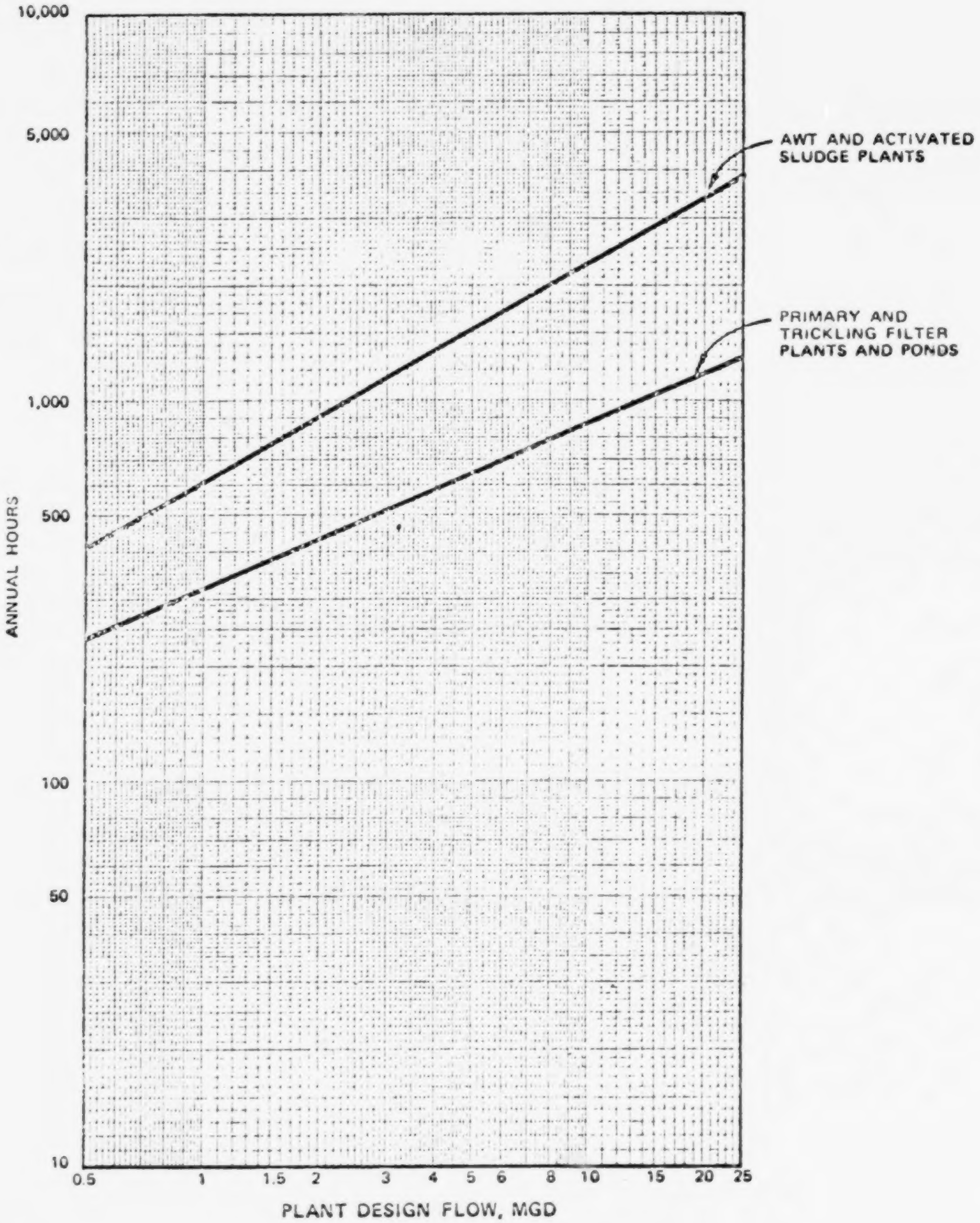
C. METHOD OF SAMPLE
[illegible]
G — GRAB SAMPLE
R — RECORDER [illegible]
M — [illegible]

D. REASON FOR TEST
H — HISTORICAL KNOWLEDGE
P — PROCESS CONTROL
C — COST CONTROL

E. FOOTNOTES
1. DIFFUSED AIR ONLY
2. WHEN DRAWING SUPERNATANT
3. FOR CONTROL OF [illegible] FLOW

RECOMMENDED MEANS OF PRESERVING SAMPLES

PRESERVATIVE	ACTION	APPLICABLE TO
$HgCl_2$	Bacterial Inhibitor	Nitrogen forms Phosphorus forms
Acid (HNO_3)	Metals solvent, prevents precipitation	Metals
Acid (H_2SO_4)	Bacterial Inhibitor	Organic samples (COD, oil and grease, organic carbon)
	Salt formation with organic bases	Ammonia, amines
Alkali (NaOH)	Salt formation with volatile compounds	Cyanides, organic acids
Refrigeration	Bacterial Inhibitor	Acidity-alkalinity, organic materials, BOD, color, odor, organic phosphorus, organic nitrogen, biological organisms (coliforms, etc)



NOTE:

INCLUDES LAB WORK DONE BY LAB STAFF AS WELL AS OPERATORS.

BASE LABORATORY
MANPOWER ESTIMATE

<table>
<tr><th>FACTOR</th><th colspan="3">ADJUSTMENT</th></tr>
<tr><td>LEVEL OF TREATMENT</td><td>PRIMARY
DECREASE 20%</td><td>T/F, PONDS, A/S
NO CHANGE</td><td>AWT
INCREASE 3% PER ADDITIONAL PROCESS</td></tr>
<tr><td>INDUSTRIAL WASTES</td><td>NONE OR CONSTANT FLOW
NO CHANGE</td><td>SEASONAL FLOW
NO CHANGE</td><td>ERRATIC FLOW
INCREASE 10%</td></tr>
<tr><td>AUTOMATIC SAMPLERS</td><td>NONE
INCREASE 10%</td><td>AT INFLUENT AND EFFLUENT
DECREASE 5%</td><td>THRU-OUT PLANT
DECREASE 2% PER POINT SAMPLED IN ADDITION TO INFLUENT AND EFFLUENT*</td></tr>
<tr><td>AUTOMATIC MONITORS AND RECORDING</td><td>NONE
NO CHANGE</td><td colspan="2">PROVIDED
DECREASE 2% PER PARAMETER MONITORED*</td></tr>
<tr><td>OFF PLANT LAB WORK</td><td>NONE
NO CHANGE</td><td>FOR RECEIVING WATER
DECREASE 10%</td><td>FOR ENTIRE PLANT
DECREASE 100%</td></tr>
<tr><td>LEVEL OF TRAINING</td><td>CERTIFICATION REQUIRED
NO CHANGE</td><td>CERTIFICATION NOT REQUIRED QUALIFIED LAB STAFF
NO CHANGE</td><td>CERTIFICATION NOT REQUIRED UNQUALIFIED LAB STAFF
INCREASE 5%</td></tr>
</table>

* MAXIMUM DECREASE EQUALS 20 PERCENT

Reproduced from best available copy.

MANPOWER ESTIMATES – TABLE OF ADJUSTMENT FOR LOCAL CONDITIONS (TALC)

LABORATORY EQUIPMENT TROUBLESHOOTING

Evaluation of equipment adequacy may readily be performed by comparing existing equipment capabilities to generally accepted listings of minimum and optimum equipment requirements found in Chapter III, "Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities."

Should equipment deficiencies be uncovered, the inspector may advise the proper municipal official of the apparent need and recommend they discuss the matter with their consulting engineer.

1. Analytical Balance
   a. Purpose:
   precision weighing
   b. Application:
   preparation of standards, gravimetric analysis of:
      total solids, suspended solids, sludge moisture, oils and grease, etc
   c. Troubleshooting Signs:
   mounted on heavy shock-proof table
   - level adjusted as necessary

2. Trip Balance
   a. Purpose:
   coarse weighing
   b. Application:
   weighing samples for MLSS, sludge wet weights, grit analysis, filter cake moisture content, preparation of chemical solutions
   c. Troubleshooting Signs:
   maintained and used in accordance with manufacturer's instructions

3. pH Meter
   a. Purpose:
   pH measurement
   b. Application:
   industrial waste, plant waste streams, electrometric determination of alkalinity, acidity and ammonia endpoints
   c. Troubleshooting Signs:
   - frequently calibrated with buffers
   - buffer solutions fresh, free of algae
   - electrodes immersed in water for storage
   - electrode tip unbroken, free of scratches
   - electrode reservoir filled
   - electrode rinsed between operations
   - samples mixed during determinations
   - sample temperature noted, meter adjusted

4. Drying Oven
   a. Purpose:
      controlled constant temperature drying of samples and glassware
   b. Application:
      determination of total, suspended, dissolved solids, sludge drying, drying of primary chemical standard reagents, drying gravimetric glassware
   c. Troubleshooting Signs:
      - oven equipped with thermometer
      - temperature controls functional
      - doors fit properly to minimize heat loss
      - chamber clean and free of scale
      - samples arranged to prevent cross contamination
      - located away from heat sensitive equipment

5. Electric Muffle Furnace
   a. Purpose:
      ignition of volatile substances
   b. Application:
      determination of volatile and fixed solids of suspended, total, activated, and digestor solids/sludges. Ignition of barium sulfate precipitates in sulfate analysis.
   c. Troubleshooting Signs:
      - furnace is equipped with temperature control
      - temperature indicator functional
      - chamber free of ash and residues
      - fumes properly exhausted
      - not located near heat sensitive equipment

6. Desiccator
   a. Purpose:
      provide moisture free/absorbent atmosphere for temporary storage of analytical powders and glassware. Ambient drying of oil and grease fractions prior to weight determination
   b. Application:
      drying of standard chemical powders, cooling of gravimetric test glassware and specimens prior to weighing (e.g., total solids oils and grease, sulfates, sludges).
   c. Troubleshooting Signs:
      - desiccator is available to every lab
      - used for all specimen cooling operations prior to reweighing
      - doors and lids properly seal
      - desiccant material is active
      - desiccant replenished when indicated

7. BOD Incubator

a. Purpose:
provide constant temperature, light-free environment for storage of BOD specimens

b. Application:
BOD incubation at 20°C

c. Troubleshooting Signs:
- temperature controls functional
- proper temperature maintained
- door closes and seals properly
- chamber clean and free of biological growths

8. Water Distillation Unit

a. Purpose:
provide distilled water having degree of purity from 0.055 micromohs/cm to 10 micromohs/cm

b. Application:
product water used in preparation of chemical solutions, BOD dilution water, bacteriology, chemical analyses, rinsing of analytical glassware

c. Troubleshooting Signs:
Difficulties encountered in bacteriological and chemical tests often relate to poor quality distilled water
- storage containers have tight covers and not exposed to airborne dust, gases, fumes
- glass storage vessels of borosilicate glass
- boiler and condenser coils free of scale
- periodic cleaning to remove sediments
- produce water frequently tested for pH and conductivity to assure adequate purity
- delivery tubing free of algae and slimes

9. Deionizer

a. Purpose:
production of high purity water by ion exchange rather than distillation

b. Application:
same as for water distillation unit. May be used to supplement distilled water production

c. Troubleshooting Signs:
- ion exchange cartridges proper type
- exchange cartridges discarded promptly when exchange capacity is exhausted
- recommended water feed rate not exceeded
- water product stored properly to avoid contamination

10. Colorimeter or Spectrophotometer

   a. Purpose:
   quantitative measurement of water quality parameters by colorimetric technique

   b. Application:
   commonly employed for phosphorus, nitrate, nitrite, hexavalent chrome, color, sulfate by turbidity method, phenols, residual chlorine, etc.

   c. Troubleshooting Signs:
   - colorimeter is delicate precision instrument and must be treated accordingly
   - common replacement parts are in stock
   - instrument properly calibrated prior to transmittance or absorbance readings
   - glass cells kept clean and free of scratches
   - filters used in accordance with operating instructions

11. Refrigerator

   a. Purpose:
   low temperature storage unit

   b. Application:
   storage and preservation of wastewater and sludge specimens – usually at 4°C. Storage of unstable chemical reagents

   c. Troubleshooting Signs:
   - temperature controls functional
   - proper temperature monitored frequently
   - interior clean and free of biological growths
   - storage capacity adequate for lab demands

12. Autoclave

   a. Purpose:
   sterilization by steam of liquids and solids

   b. Application:
   sterilization of dilution water, glassware, sample containers, growth media, related supplies necessary for bacteriological tests

   c. Troubleshooting Signs:
   - temperature and pressure controls functional
   - proper time – temperature for materials being sterilized
   - confirmation of adequacy of sterilization by test strips, tape indicators, etc
   - materials sterilized have been properly wrapped and sealed to prevent contamination
   - sterilized materials properly stored to avoid contamination

13. Electric Hotplate and Heater

   a. Purpose:
      variable temperature heating of liquids and solids

   b. Application:
      preparation of analytical solutions, evaporation, concentration, hydrolysis, digestion, other analytical operations

   c. Troubleshooting Signs:
      - number of hotplates and heaters adequate
      - temperature controls functional

14. Dissolved Oxygen Analyzer

   a. Purpose:
      instrumental analysis of dissolved oxygen in liquids and gases

   b. Application:
      analysis of dissolved oxygen, BOD testing sewage, industrial wastes, stream samples

   c. Troubleshooting Signs:
      - frequent and proper calibration of instrument by wet chemical or other means
      - probe stored in water or moisture saturated atmosphere between testings
      - probe surfaces cleaned according to manufacturer's directions
      - probe electrolyte and membranes replaced as indicated
      - sample velocity at probe tip maintained during determinations
      - membrane replacement kit in stock

15. Bacteria Incubator

   a. Purpose:
      controlled constant temperature for storage and cultivation of bacteria and biological specimens

   b. Application:
      total coliform, fecal streptococci, other bacteriological testing

   c. Troubleshooting Signs:
      - temperature controls functional
      - thermometer or other temperature monitor system in place and operable
      - chamber clean and free of spillage and/or biological growths
      - doors close and seal properly
      - unit located away from temperature extremes

16. Water Bath Incubator

a. Purpose:
controlled constant temperature bath

b. Application:
fecal coliform bacteria testing, digestion of wastewater specimens, assist color development in nitrate testing

c. Troubleshooting Signs:
temperature controls functional
- thermometer or other temperature monitor system in place and operable
- chamber and bath water clean, free of rust and sediments
- adequate cover and seal to minimize evaporative losses
- bath water level maintained

17. Conductivity Meter

a. Purpose:
measurement of solution electrical conductance and resistance

b. Application:
quality control testing of distilled water, screening of water and waste specimens

c. Troubleshooting Signs:
- electrode clean and kept in distilled water between determinations
- frequent calibration against known electrolyte references
- sample temperature corrections made

18. Total Organic Carbon Analyzer

a. Purpose:
instrumental analysis of carbon fractions in solutions by combustion/infrared technique

b. Application:
rapid assay of total, inorganic, and organic carbon fractions in water and waste samples. Data may correlate with BOD and COD, and (may be) applied accordingly in treatment plant process control

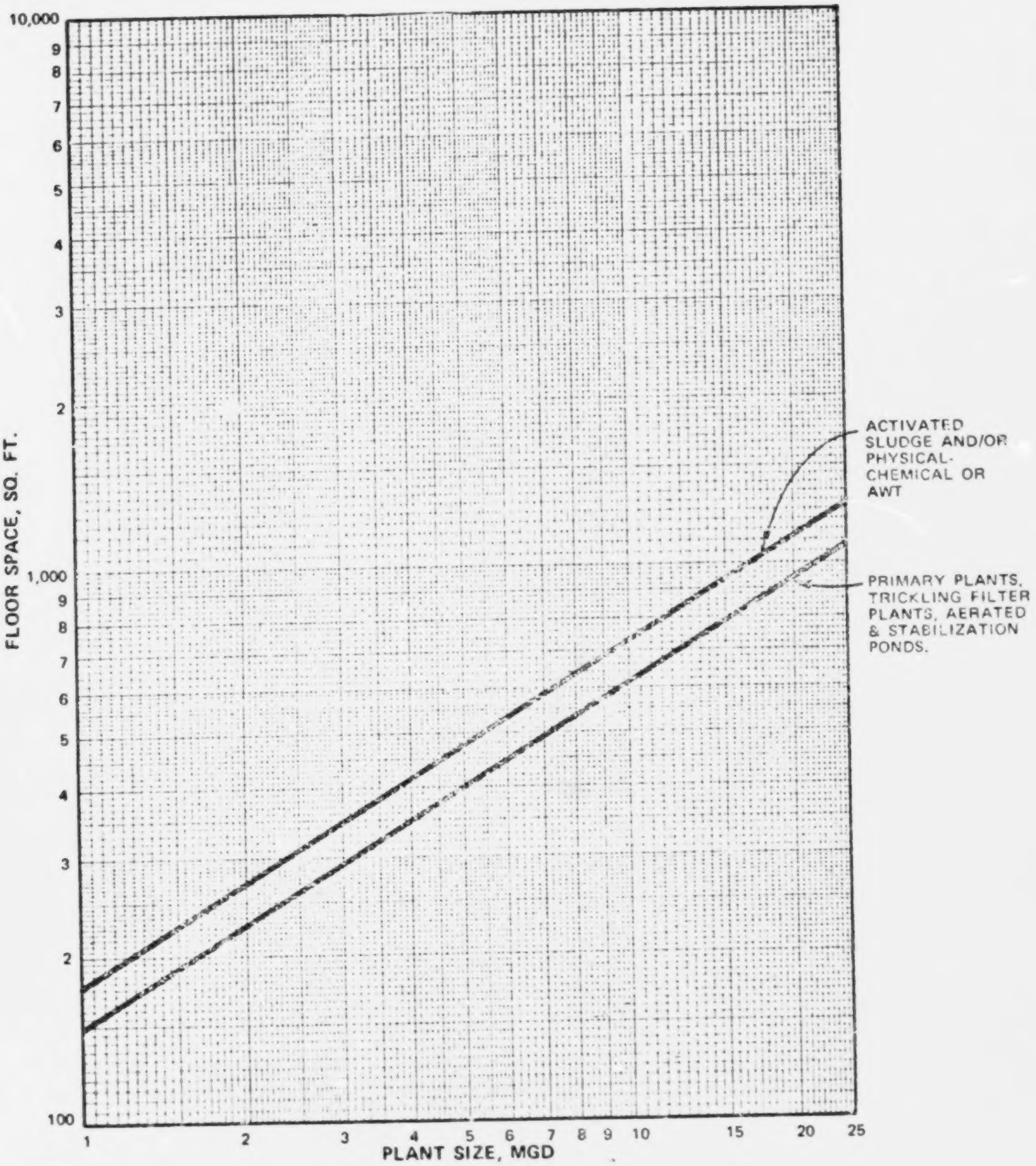
c. Troublshooting Signs:
- inspector should refer questions to qualified person due to complexity of instrument and test procedure

19. Atomic Absorption Spectrophotometer

a. Purpose:
instrumental analysis of metal ions by atomic absorption or emission technique

b. Application:
analysis of NPDES required heavy metal ions, monitoring industrial wastes for possible toxic metal ions

c. Troubleshooting Signs:
- determine instrument is properly installed with fume exhaust system
- inspector should refer questions to qualified person due to complexity of instrument and testing procedures

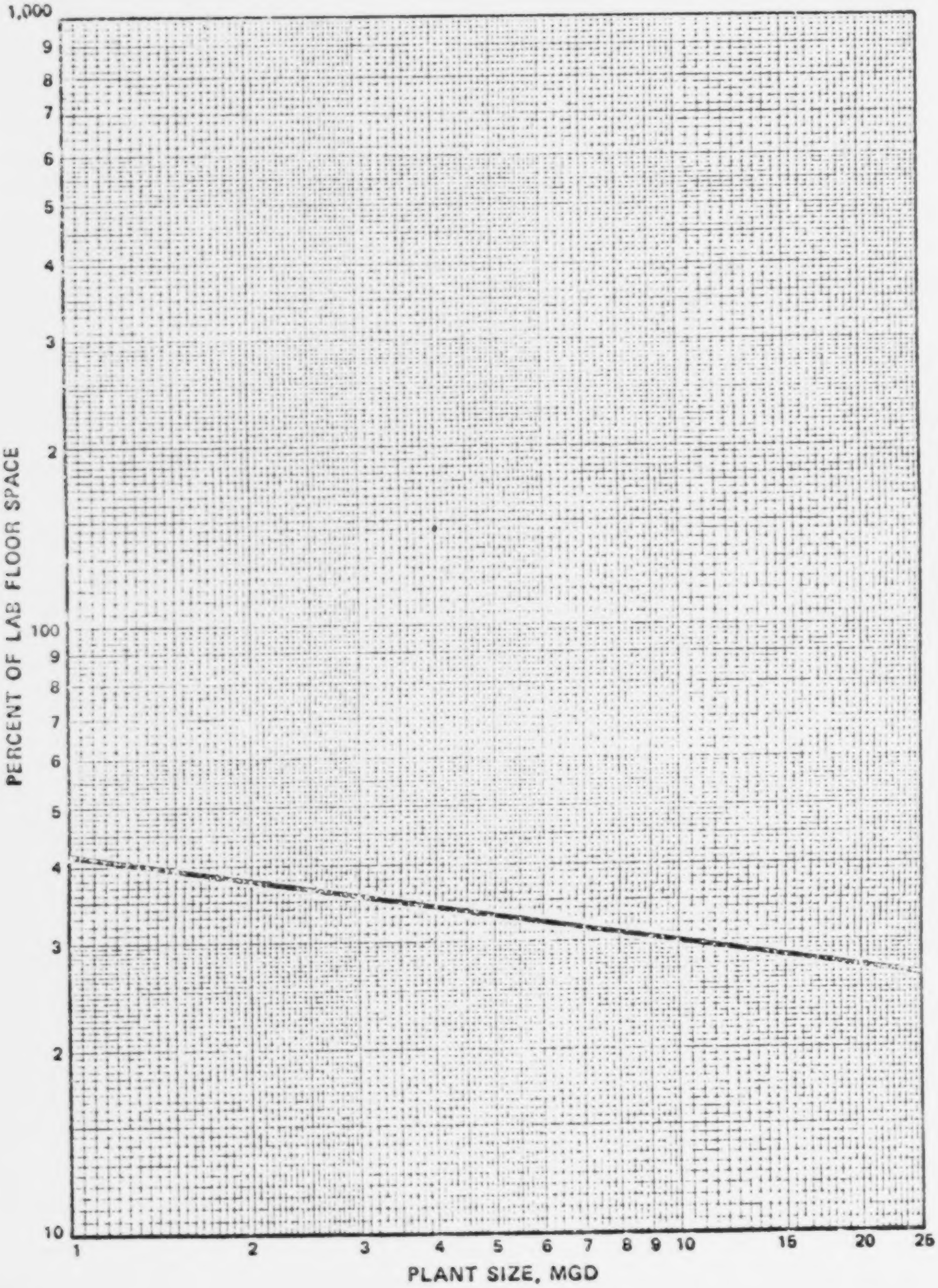


NOTES:

1. MINIMUM FLOOR SPACE REQUIRED FOR PLANTS LESS THAN 1 MGD IS 180 SQ. FT. FOR ACTIVATED SLUDGE, PHYSICAL-CHEMICAL, AND AWT PLANTS, AND 150 SQ. FT. FOR PRIMARY, TRICKLING FILTER, AND POND TYPE PLANTS.
2. INCLUDES SPACE FOR CONDUCTING LABORATORY ADMINISTRATIVE DUTIES.

FIGURE C–1

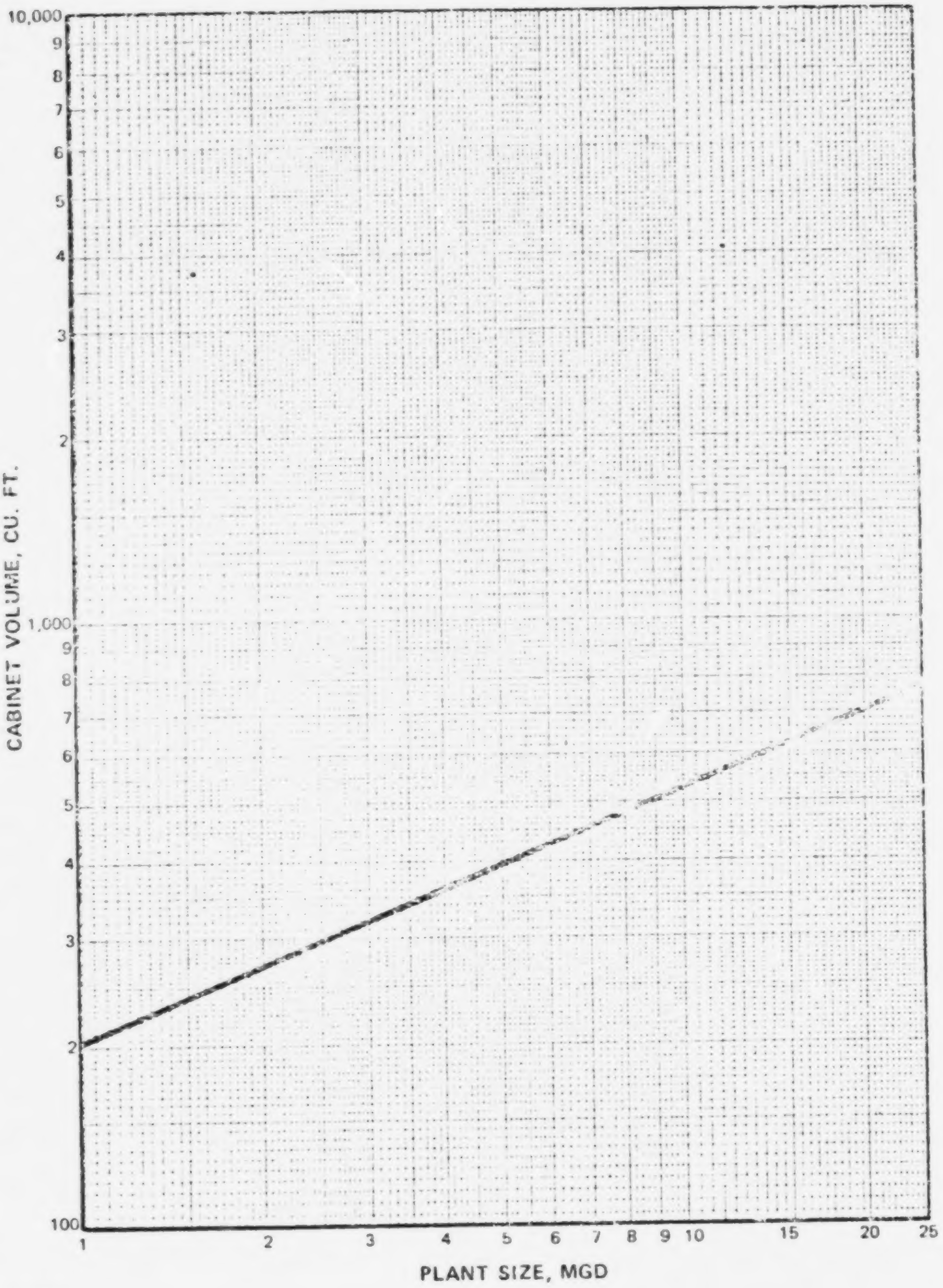
ESTIMATED LAB FLOOR SPACE



NOTE:

MINIMUM PERCENT OF FLOOR SPACE, REQUIRED FOR BENCH AREA, FOR PLANTS LESS THAN 1 MGD IS 40 PERCENT.

ESTIMATED BENCH AREA



NOTE:

MINIMUM CABINET VOLUME REQUIRED
FOR PLANTS LESS THAN 1 MGD IS
200 CU. FT.

ESTIMATED CABINET VOLUME

REFERENCES – LABORATORY PRACTICES

Gilbert, W.G. Municipal Wastewater Treatment: The Relation of Operation and Maintenance Activities to Plant Efficiency. Presented at 48th Annual Conference, Water Pollution Control Federation, Miami Beach, October 1975.

West, A.W. Operational Control Procedures for the Activated Sludge Process, Part II, Control Tests. Environmental Protection Agency, National Field Investigations Center, Cincinnati. 1973.

Hayes, R.B., and C.S. Zickefoose. Operator's Pocket Guide to Activated Sludge, Part II, Process Control and Troubleshooting. Stevens, Thompson & Runyan, Inc., Portland, Oregon, 1975.

URS Research Company. Procedures for Evaluating Performance of Wastewater Treatment Plants. U.S. Environmental Protection Agency.

Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities. Environmental Protection Agency, Office of Water Program Operations, Washington, D.C. 1973.

Handbook for Analytical Quality Control in Water and Wastewater Laboratories. Environmental Protection Agency, Analytical Quality Control Laboratory, Cincinnati, Ohio. 1972.

Manual for Methods of Chemical Analysis of Water and Wastes. Environmental Protection Agency, Methods Development and Quality Assurance Research Laboratory, Cincinnati, Ohio. 1974.

Standard Methods for the Examination of Water and Wastewater. American Public Health Association, Fourteenth Edition.

LESSON – FLOW MEASUREMENT

Instructor Overview of Lesson

Entry Level Behavior Students will have had University training in Sanitary Engineering, waste treatment and/or related sciences or equivalent in experience and training. Some field experience in inspecting flow measurement systems in treatment plants, but no experience in operating waste treatment facilities

As a prerequisite to this course, it is recommended that the student will be able to

1. Identify treatment plant process units
2. Describe treatment plant process units and equipment in technical terms
3. Identify and explain the purpose of components of treatment plant process units, how they work, and why they are important to the overall process
4. Describe the normal operating procedures for treatment plant process unit components
5. Identify when treatment plant process units are not operating properly

Instructor Objectives The principal instructor objectives for this lesson are

1. To emphasize the importance of flow measurement as means of understanding plant processes, operations and problems
2. To relate types of flows within a plant to plant operations
3. To stress the use of the Process of Troubleshooting in relation to operational problems involving flow measurements

References Note list of references included with Student Notebook materials

Total Length of Lesson 1 Hour for 2 Lesson Subdivisions

LESSON OVERVIEW

Subdivision Title & Time	Major Student Objectives	Key Points & Content	Approach	Materials
1. Flow Measurement and Treatment Plant Operation	1. List purposes of flow measurements and types of flows.	1. Flow measurement purposes.	1. Follow subject outline with slide series.	1. Slide series and slide key.
	2. Identify relation of knowledge of flows to plant operations.	2. Types of flows.	2. Student group exercise using work sheets & flow diagram.	2. Student group work sheet and flow diagram.
30 Minutes	3. Characterize flows as linkages between plant processes that comprise the overall waste treatment system.	3. Impact of Flow Volumes on plant performance.	3. Reporting by students on results of group exercise.	
2. Troubleshooting Treatment Plant Flow Measurement	1. Identify flow measurement devices.	1. Process of troubleshooting.	1. Follow subject outline with slide series.	1. Slide series and slide key.
	2. Recognize common flow measurement problems.	2. Poor flow measurements can create plant operating problems.	2. Encourage student discussion and participation.	2. EPA Manual, "Evaluating the Performance of Wastewater Treatment Plants," p. 109.
30 Minutes	3. Describe troubleshooting procedures for flow measurement problems.	3. Flow measurement devices, and common problems.	3. Use troubleshooting guide, by referring to Student Notebook.	3. Student Notebook – Troubleshooting Guide and Flow Equations.
	4. Identify field expedients for in-plant flow measurement.	4. Systematic troubleshooting guide.		4. Process of Troubleshooting Chart.
		5. Expedients for flow measurement problem solving.		

LESSON – FLOW MEASUREMENT

Presentation Options For Course Director

The 60 minute lesson, FLOW MEASUREMENT, stresses an important aspect of wastewater treatment plant operations. Although the students in the course should, by virtue of the entry level requirements, be familiar with flow measurement devices, the emphasis of this lesson may be new to the students – because it stresses flow measurement as a key to plant operations.

It is recommended that this lesson be presented as designed, in one hour, unless there is a specific need to expand the scope for the particular students for whom the course is being presented. Options for modfying the lesson include:

Subdivision 1 – Flow Measurement and Treatment Plant Operation

This subdivision can be enhanced by expanding Section III, which is the student exercise on flow measurement and plant performance. If desired, flow diagrams for activated sludge and oxidation lagoons can be used to relate flow measurement to plant operations.

Subdivision 2 – Troubleshooting Treatment Plant Flow Measurement

If students are unfamiliar with flow measurement devices, slides may be shown which illustrate such devices. Additional time may be used to discuss the proper maintenance and use of common flow measurement devices used in treatment plants.

FLOW MEASUREMENT

LESSON PLAN – SUBDIVISION 1 **TIME: 30 MINUTES**

Title: Flow Measurement and Treatment Plant Operation

Instructor Objectives: To emphasize the importance of knowing the volume of flows into and within a treatment plant as a means of better understanding plant processes, operations and problems. To familiarize the students with the types of flows to be measured within a treatment plant, and with how flow measurements relate to knowledge of plant processes and operations.

Student Objectives: As a result of this lesson subdivision, students will be able to do the following:

1. List the reasons why flow volumes into and within a treatment plant are measured and recorded
2. Identify the type of flows within a treatment plant that should be measured and recorded
3. List locations and operations within a plant where flow measurement should be carried out
4. Identify aspects of treatment plant performance which would be affected by an operator's inability to accurately determine flow volumes
5. Characterize a waste treatment plant as a system, and identify the flows within a plant as key linkages between the various plant processes that comprise the overall *waste treatment system.*

Training Materials:

Slide series of 4 word slides with slide key.

Student Notebook section on Flow Measurement, specifically Flow Diagram, page FM-1, and Problem Answer Sheets, FM-2 and FM-3.

Classroom Set-up:

A normal classroom set-up will be required. Students must be seated with their student groups

35 mm carousel slide projector with remote controls

Large screen (8 ft x 10 ft)

Chalkboard or easel

Pointer

Subdivision Schedule:

Within the 30 minute time period, the following schedule should be observed in presenting the lesson plan outline and in overseeing student work group activities

TIME	SUBJECT
0 – 5 Minutes	Purpose of Flow Measurement
5 – 10 Minutes	Types of Flows to Measure
10 – 25 Minutes	Flow Measurement and Plant Performance
25 – 30 Minutes	Discussion of Flow Measurement Problem

Subdivision Approach:

The instruction approach for this subdivision is designed to stimulate student involvement and participation, therefore, the instructor should serve more as a catalyst than a teacher.

Students who meet the prerequisites of the course will be familiar with flow measurement techniques, devices used, formulas for computing flow, etc. Therefore, the mission of the instructor is not to teach students about flow measurement per se, but rather to convey to the students, and to have them determine for themselves, that *flow measurement is a key factor in understanding what is really happening in a treatment plant*, and thus in troubleshooting treatment plant problems.

Sections I and II of the lesson outline for this subdivision utilize key word slides as a *means* for generating student input and discussion on flow measurement.

Section III of the lesson outline involves student group activity. Student groups are to use the work sheets probided in the Student Notebook. All members of each group should be encouraged to participate in the group exercise. The instructor should be present during this period and answer any questions that the student groups have about the assignment.

At the end of the 15 minute student group assignments, the instructor is to have each group briefly report on the results of its work. The instructor should then summarize and move on the Subdivision 2.

LESSON OUTLINE

I. Purposes of Flow Measurement (5 minutes)

A. "PURPOSES OF FLOW MEASUREMENT"

B. "PURPOSES OF FLOW MEASUREMENT"

- Measure organic and hydraulic loads
- Provide operating and performance data
- Process control
- Troubleshoot problems
- Measure loads by source
- Compute costs
- Build long term record

II. Types of Flows to be measured (5 minutes)

A. "TYPES OF FLOWS TO MEASURE"

B. "TYPES OF FLOWS TO MEASURE"

- Influent
- Internal — to balance flow between parallel components
- Side streams
- Chemical feeds
- Effluent

For more detail on which flows should normally be measured, the following detailed outline can be used:

KEY POINTS & INSTRUCTOR GUIDE

SLIDE FM-1 (word)
Use this slide to intoduce subject.

Guide: Use opening 5 minutes to "warm up" class for discussion.

Have class contribute input on why flow measurement is important. Have a student record reasons on chalkboard.

After 5 minutes, go to slide FM-2 with prepared list of purposes.

SLIDE FM-2 (word)

SLIDE FM-3 (word)
Use this slide to introduce subject.

Seek student discussion on what flows normally should be measured in treatment plant operations.

SLIDE FM-4 (word)

LESSON OUTLINE

1. Influent Flows
    a. Domestic waste
    b. Industrial waste
    c. Storm flow
    d. Infiltration
    e. Septage
2. Internal Flows
    a. Distribution to tanks
    b. Uniform discharge through ports, weirs, etc
3. Side Streams
    a. Return activated sludge
    b. Waste activated sludge
    c. Filtrates
    d. Elutrates
    e. Supernates
4. Chemical Feeds
    a. Disinfection
    b. Coagulants
    c. pH control
    d. Sludge conditioners
5. Effluent

III. Flow Measurement and Plant Performance (15 minutes)

A. Assign students to work in predesignated student groups

B. Refer students to problem work sheets in Student Notebook
  1. Page FM-1, Trickling filter flow diagram
  2. Pages FM-2 & 3, Problem answer sheets (These sheets are included in the instructor's lesson plan as pages FM 1-5 thru FM 1-7)

C. Have student groups complete the answer sheets – pages 2 & 3 – for this problem. Stress the importance of discussion between all of the members of each student group

D. After 15 minutes, proceed to a class discussion of the results of the problem

IV. Discussion of Flow Measurement Problem (5 minutes)

Have students discuss the results of the assigned problem

Stress discussion of Question 2 – Treatment performance affected by lack of accurate flow measurement

KEY POINTS & INSTRUCTOR GUIDE

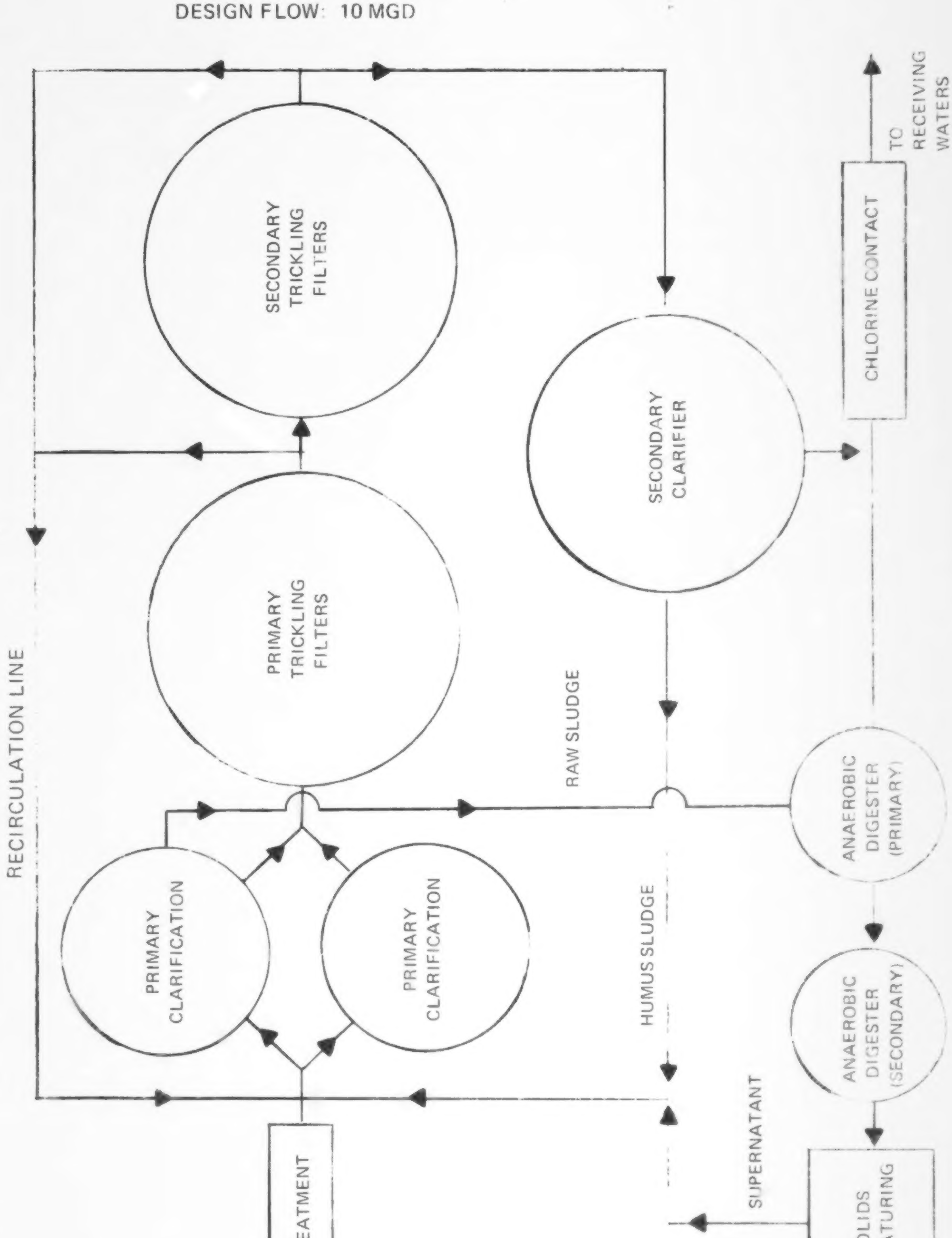
Guide: The purpose of this section is to highlight the following concepts.

1. Treatment plants function as a system – linked by a variety of flows.

2. Accurate flow measurements are needed to understand the waste treatment system.

3. Plant performance may be affected if there are not good flow measurements.

Key Point: Good flow measurement is one key to plant performance.


DESIGN FLOW: 10 MGD
SECONDARY TRICKLING FILTERS
PRIMARY TRICKLING FILTERS
RECIRCULATION LINE
PRIMARY CLARIFICATION
PRIMARY CLARIFICATION
PRETREATMENT
SECONDARY CLARIFIER
CHLORINE CONTACT
TO RECEIVING WATERS
RAW SLUDGE
HUMUS SLUDGE
ANAEROBIC DIGESTER (PRIMARY)
ANAEROBIC DIGESTER (SECONDARY)
SUPERNATANT
SOLIDS DENATURING

TRICKLING FILTER FLOW DIAGRAM

GROUP ______________ **ANSWER SHEET – Page 1**

MEASURING FLOW VOLUMES – IMPACT ON PLANT OPERATIONS

1. Using the Trickling Filter Flow Diagram, identify the following major plant flows – by numbering key points on the flow diagram according to the type of flow, as follows:

    1. Influent flows
    2a. Internal flows – parallel distribution
    2b. Internal flows – series distribution
    3. Side streams (sludge, supernatant, etc)
    4. Chemical feeds – actual or possible
    5. Effluent

2. For each of the following processes, determine whether plant performance would be affected by the operator's inability to accurately measure flow volumes identified in question 1.

Process	Yes or No Performance Affected	Possible Indicators of Poor Performance
a. Pretreatment		
b. Primary Clarification		
c. Trickling Filter		

Measuring Flow Volumes – Impact on Plant Operations – Continued

Process	Yes or No Performance Affected	Possible Indicators of Poor Performance
d. Secondary Clarifier		
e. Digesters		
f. Chlorination		
g. Effluent Quality		

3. For each flow identified in Question 1, identify a flow measurement device that would normally be used.

FLOW MEASUREMENT

LESSON PLAN – SUBDIVISION 2 **TIME: 30 MINUTES**

Title: Troubleshooting Treatment Plant Flow Measurement

Instructor Objectives: To present the basic elements of the Process of Troubleshooting as it relates to operational problems in the measurement of treatment plant flows. To stress the use of flow measurement as a means of solving operational and process control problems within a wastewater treatment plant.

Student Objectives: As a result of this lesson subdivision, students will be able to do the following:

1. List commonly used flow measurement devices and identify the specific applications and uses of flow measurement devices in a treatment plant
2. Recognize common problems found in flow measurement devices and list their possible causes
3. Identify indicators of plant performance that may signify unreliable flow measurements
4. Describe systematic procedures for troubleshooting flow measurement systems in wastewater treatment plants
5. Describe and carry out observations and tests that may be performed for troubleshooting flow measurement devices
6. List and explain corrective actions to be implemented in troubleshooting flow measurement problems
7. Identify field expedient procedures for measuring flow when existing devices are inadequate, or when there are no existing devices
8. Engage in "Creative Troubleshooting" to correct problems in flow measurement and to supplement existing means for measuring flows in treatment plants

Training Materials:

Slide series with slide key

EPA Manual "Evaluating the Performance of Wastewater Treatment Plants," page 109

Student Notebook section of Flow Measurement, including flow measurement troubleshooting guide, page FM-4, and Flow Equations, page FM-7

Classroom Set-up:

A normal classroom set-up will be required. Students should be seated with their student groups

35 mm carousel slide projector with remote controls

Large screen (8 ft x 10 ft)

Chalkboard or easel

Pointer

Subdivision Schedule:

Within the 30 minute time period, the following schedule should be observed in presenting the lesson plan outline

TIME	SUBJECT
0 – 5 Minutes	Approach to Troubleshooting
5 – 15 Minutes	Identifying Flow Measurement Devices and Common Problems
15 – 20 Minutes	Systematically Troubleshooting Flow Measurement
20 – 25 Minutes	Flow Measurement Expedients
25 – 30 Minutes	Lesson Summary

Subdivision Approach:

The instructor is to rely upon the lesson outline, and particularly upon the slide series and slide key. Student discussion and participation should be encouraged

Section III, instructor is to refer to and use the flow measurement troubleshooting guide in the Student Notebook

Section IV and V, instructor should maximize student input, and use the word slides provided only to the minimum degree necessary

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
I. Approach to Troubleshooting Flow Measurement Problems (5 minutes)	Refer class to Process of Troubleshooting Guide in Student Notebook.
A. "INITIAL STEPS IN TROUBLESHOOTING FLOW MEASUREMENT PROBLEMS" • What do past records indicate? • What does the operator think? • What observations and tests need to be made? • How is plant performance affected? • What measurement devices exist?	SLIDE FM-5 (word) Key Point: The instructor should focus on the overall Process of Troubleshooting for solving plant problems, and then on the specific possibility that deficiencies in flow measurement may be partially responsible.
B. "WHAT SYMPTOMS EXIST OF PLANT PROBLEMS?" • Low removals • Frequent breakdowns • Excessive maintenance • Poor sludges • Nuisances	SLIDE FM-6 (word)
C. "CAN ALTERNATIVE CAUSES OF PLANT PROBLEMS BE FOUND? CAN POOR FLOW MEASUREMENTS BE POSSIBLY LISTED AS A CAUSE FOR PLANT PROBLEMS?"	SLIDE FM-7 (word)
D. "CAN POOR FLOW MEASUREMENTS BE RESPONSIBLE FOR" • Hydraulic overloads • Organic overloads • Unbalanced flows • Inadequate disinfection • Poor sludge treatment	SLIDE FM-8 (word) Guide: Instructor should seek class discussion on this question.

LESSON OUTLINE

II. Identifying Flow Measurement Devices and Common Problems Associated with Them (10 minutes)

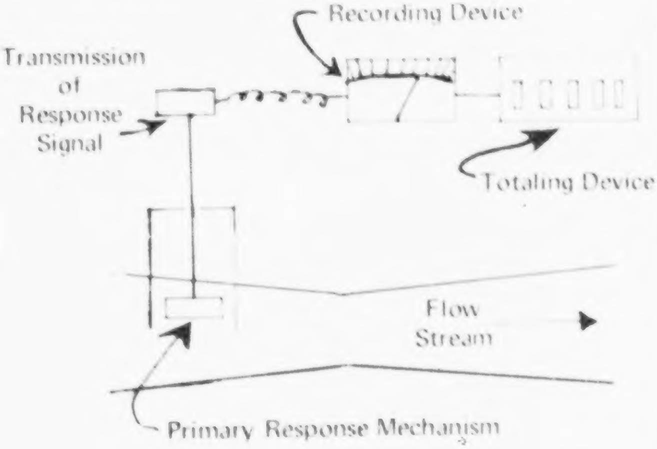
A. "COMMON TYPES OF FLOW MEASUREMENT DEVICES"

- Meters
- Constrictors
    - Flumes
    - Weirs
    - Nozzles
- Pumps

B. "ELEMENTS OF A COMPLETE FLOW MEASUREMENT SYSTEM"

- Primary response mechanism
- Transmission of response signal
- Recording device
- Totaling device

C. "SCHEMATIC FLOW MEASUREMENT SYSTEM"


Recording Device
Transmission of Response Signal
Totaling Device
Flow Stream
Primary Response Mechanism

KEY POINTS & INSTRUCTOR GUIDE

Note: Students with the proper prerequisites should have sufficient knowledge about flow measurement devices. Therefore, it is not necessary to describe flow measurement devices in detail. Students may be referred to other sources for additional information.

Note: Picture slides of various flow measurement devices may be added if they can be obtained.

SLIDE FM-9 (word)

SLIDE FM-10 (word)
Quickly go to next slide which illustrates.

SLIDE FM-11 (word)

This diagram is meant to be schematic of all systems, and not represent any flume, weir, meter or any other specific device.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
D. "FLOW METERS - COMMON VARIETIES" • Magnetic Gaining wide use for inflows, recirculation and sludge • Venturi • Turbine	SLIDE FM 12 (word) If any picture slides of flow meters are available, they should be used here
E. "COMMON METER PROBLEMS" • Improper location • Improper size • Unsuitable for material being measured • Poor instrumentation • No totalizer • Unreliable due to age or condition	SLIDE FM 13 (word) Refer students to page 109 EPA Manual "Evaluating the Performance of Wastewater Treatment Plants" which discusses metering
F. "CORRECTIVE ACTIONS FOR METERS" • Good continual cleaning and maintenance • Proper installation at the right location • Calibrate and monitor transmission and recording elements, replace or repair if necessary	SLIDE FM 14 (word)
G. "FLUMES AND NOZZLES" • Parshall Flume Widely used due to simplicity and accuracy • Kennison Flow Nozzle Measures flow in pipes not running full	SLIDE FM 15
H. "COMMON FLUME PROBLEMS" • Improper location or size • Turbulence or obstructions upstream • Float location, malfunction, freezing • Buildup of solids • Downstream submergence • Poor instrumentation	SLIDE FM 16
I. "CORRECTIVE ACTIONS FOR FLUMES" • Calibration • Removal of obstructions, solids • Minimize turbulence	SLIDE FM 17
J. "WEIRS" • Rectangular • Cipolletti (Trapezoidal) • V Notch • Proportional	SLIDE FM 18

LESSON OUTLINE

K. "COMMON WEIR PROBLEMS"

- Overall accuracy
- Buildup of solids
- Not calibrated
- Poor design or installation
- No charts or nomographs

L. "CORRECTIVE ACTIONS FOR WEIRS"

- Calibration
- Development of accurate charts
- Cleaning and maintenance
- Minimize turbulence and surge action

M. "PUMPS — PROBLEMS WITH USING PUMPS TO MEASURE FLOWS"

- No true knowledge of pump characteristics
- No counters on positive displacement pumps
- No timers on fixed speed units
- No individual meters

N. "CORRECTIVE ACTIONS FOR PUMPS"

- Install meters if possible at key locations
- Install counters and timers
- Calibrate by measuring actual flow volumes and rates
- Calibrate to allow visual observations with staff groups

III. Systematically Troubleshooting Flow Measurement at Treatment Plants (5 minutes). USING THE FLOW MEASUREMENT TROUBLESHOOTING GUIDE

A. Analyze Plant Flow Measurement Capability

1. Review plans and flow diagrams

a. Define plant processes, operations, and sub-systems

b. Locate sources and discharge points of all streams and side streams

c. Study plant flexibility with respect to possible mode change

KEY POINTS & INSTRUCTOR GUIDE

SLIDE FM-19

SLIDE FM-20

SLIDE FM-21

SLIDE FM-22

Refer students to Student Notebook page FM-4. Use the "Flow Measurement Troubleshooting Guide" for this section of the outline. Briefly review this outline.

Note: This is presented as a systematic guide to students for troubleshooting flow measurement problems at treatment plants.

Key Point: Use of the Process of Troubleshooting with respect to flow measurement.

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

- d. Locate measuring devices and evaluate their adequacy with respect to
  - 1. type of device used
  - 2. location
  - 3. size
  - 4. recording and totalling capability
  - 5. overall installation

2. Tour facility
   - a. Observe physical layout and location of measuring devices, valves, pumps and tanks
   - b. Discuss plant performance with operator, plant personnel
   - c. Seek the opinions of plant personnel
   - d. Learn color coding, labeling and unit designations
   - e. Examine measuring devices, their installation and condition

3. Examine flow charts
   - a. Evaluate trends
   - b. Check for storm response
   - c. Identify unusual deviations

4. Study manufacturer's recommendations for user maintenance
   - a. Review maintenance records

5. Examine instrumentation
   - a. Check for evidence of operator tampering

6. Inspect weirs and flumes
   - a. Measure appropriate heads
   - b. Check instrument readings
   - c. Check for obstructions, turbulence and condition of device
   - d. Disturb floats, check for response on flow charts
   - e. Observe surge action

B. Formulate Alternatives

1. Possible causes to plant problems
   - a. Poor control over specific treatment processes

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

b. Organic overloading

c. Poor management and administration

-
-

n. Difficulties or inaccuracies in measuring flows

2. Prioritize alternatives and corrective actions
3. Confirm opinion if possible
4. Get outside help if necessary
5. There may not be one single "right" answer

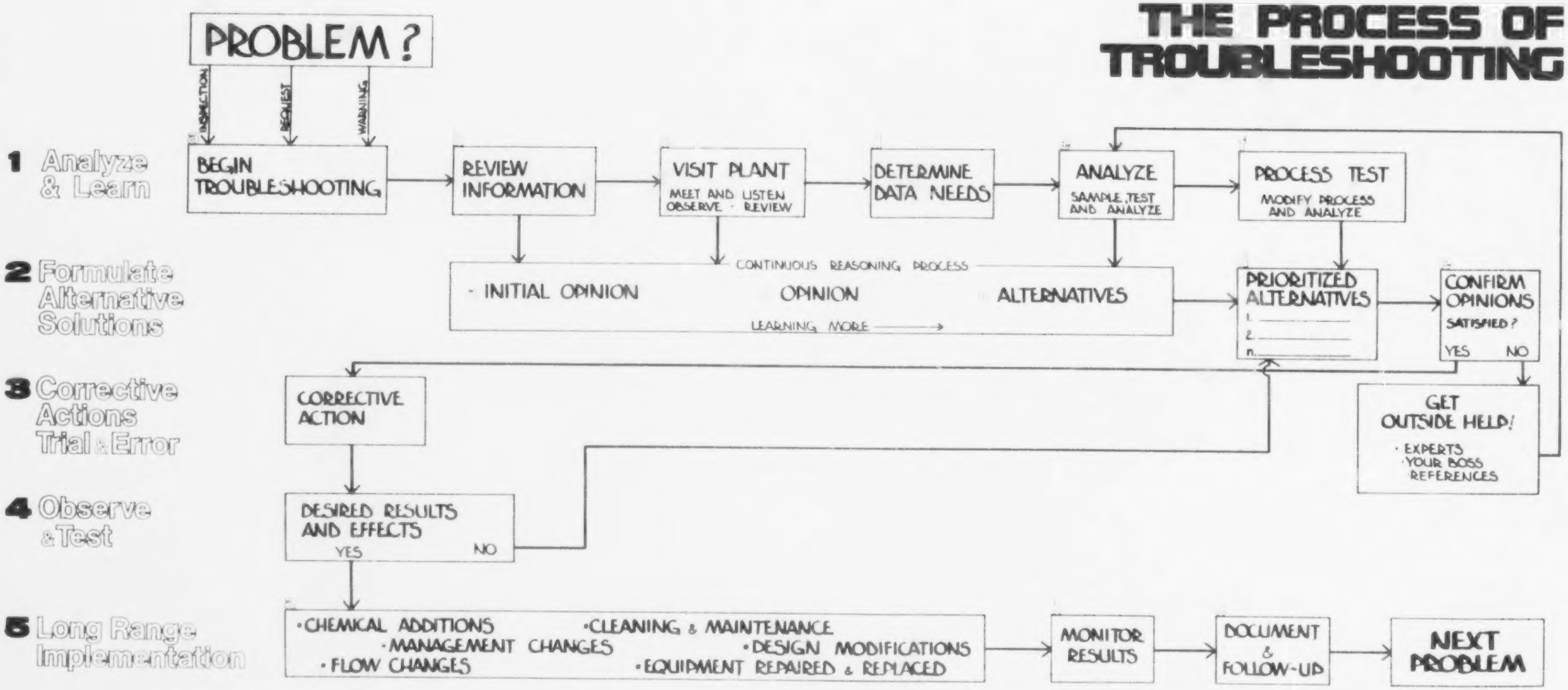
C. Take appropriate corrective actions, observe and test. With regard to flow measurement problems, this may mean –

1. Major Corrective Action
   a. Install metering equipment at points where flow data is necessary
   b. Repair existing flow measurement systems
   c. Calibrate existing flow measurement systems
   d. Modify or replace systems for transmitting, recording or totalling flow data
   e. Correct faulty installations, and conditions which cause flow measurement devices to operate improperly
   f. Cleaning and preventive maintenance
   g. Develop accurate charts
   h. Install counters and timers on pumps
2. Expedient Actions on a Temporary Basis – Until Permanent Improvement Can be Made
   a. Improve or "fix-up" present systems
   b. Install temporary recorders
   c. Calibrate existing devices
   d. Install devices to facilitate quick measurements in the future
   e. Install temporary measuring systems
   f. Calculate flows from pipe or channel measurements
   g. Compute flows using pump curves

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
3. Flow balancing and equalization within the plant a. Equalize flows to parallel plant units b. Increase or decrease flows where necessary for process control c. Balance solid loadings by using centrifuge d. Modify chemical feed rates	
IV. Flow Measurement Expedients (Or what to do when there's nothing else to do) (5 minutes)	Guide: Instructor should maximize student input into this section.
A. Ask students to discuss what they would do to measure flows at plants with non-existent or inadequate flow measurement capability *if necessary* – use the folowing 5 slides to cover this subject	
"FLOW MEASUREMENT EXPEDIENTS FOR PLANT TROUBLESHOOTING"	SLIDE FM-23 (word)
• Improve present systems to produce better results • Calibrate existing systems • Provide for future measurements • Set-up temporary flow measurement devices	Guide: These are the purposes of various flow measurement expedients.
"EXPEDIENTS – IMPROVEMENT OF PRESENT SYSTEMS"	SLIDE FM-24 (word)
• Baffle turbulence and surges • Clean and maintain systems • Install temporary recorders if necessary	
• Others	Have students suggest "others."
"EXPEDIENTS – CALIBRATION"	SLIDE FM-25 (word)
• Calibrate weirs and flumes • Calibrate pumps by timing periods required to fill known volumes at various pumping speeds	
• Others	Have students suggest "others."
"EXPEDIENTS – FUTURE MEASUREMENTS"	SLIDE FM-26 (word)
• Install counters on positive displacement pumps • Install staff gauges at time flow measurement equipment is calibrated	
• Others	Have students suggest "others"

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
"EXPEDIENTS – TEMPORARY DEVICES" • Install temporary weirs or flumes in collection system in plant at discharge • Calculate flows – California Pipe Method or other methods	SLIDE FM-27 (word) Refer students to Student Notebook page FM-7 – Flow Equations and Discharge Formulae.
• Use pump curves to compute flows • Others	Have students suggest "others."
V. Summary – Troubleshooting for Flow Measurement Problems (5 minutes)	
"SUMMARY – TROUBLESHOOTING FOR FLOW MEASUREMENT" • Flow measurement is a key to plant operations and troubleshooting • Impact on plant operations • Devices are part of *flow measurement systems* • Systematic troubleshooting approach applies to flow measurement	SLIDE FM-28 (word)
• Field expedients may be necessary	Guide: Call for student comments and questions to "wrap-up" lesson.

THE PROCESS OF TROUBLESHOOTING


PROBLEM ?
INSPECTION
REQUEST
WARNING
1 Analyze & Learn
2 Formulate Alternative Solutions
3 Corrective Actions Trial & Error
4 Observe & Test
5 Long Range Implementation
BEGIN TROUBLESHOOTING
REVIEW INFORMATION
VISIT PLANT
MEET AND LISTEN
OBSERVE · REVIEW
DETERMINE DATA NEEDS
ANALYZE
SAMPLE, TEST AND ANALYZE
PROCESS TEST
MODIFY PROCESS AND ANALYZE
CONTINUOUS REASONING PROCESS
· INITIAL OPINION
OPINION
ALTERNATIVES
LEARNING MORE
PRIORITIZED ALTERNATIVES
1.
2.
n.
CONFIRM OPINIONS
SATISFIED ?
YES
NO
GET OUTSIDE HELP!
· EXPERTS
· YOUR BOSS
· REFERENCES
CORRECTIVE ACTION
DESIRED RESULTS AND EFFECTS
YES
NO
· CHEMICAL ADDITIONS
· MANAGEMENT CHANGES
· FLOW CHANGES
· CLEANING & MAINTENANCE
· DESIGN MODIFICATIONS
· EQUIPMENT REPAIRED & REPLACED
MONITOR RESULTS
DOCUMENT & FOLLOW-UP
NEXT PROBLEM

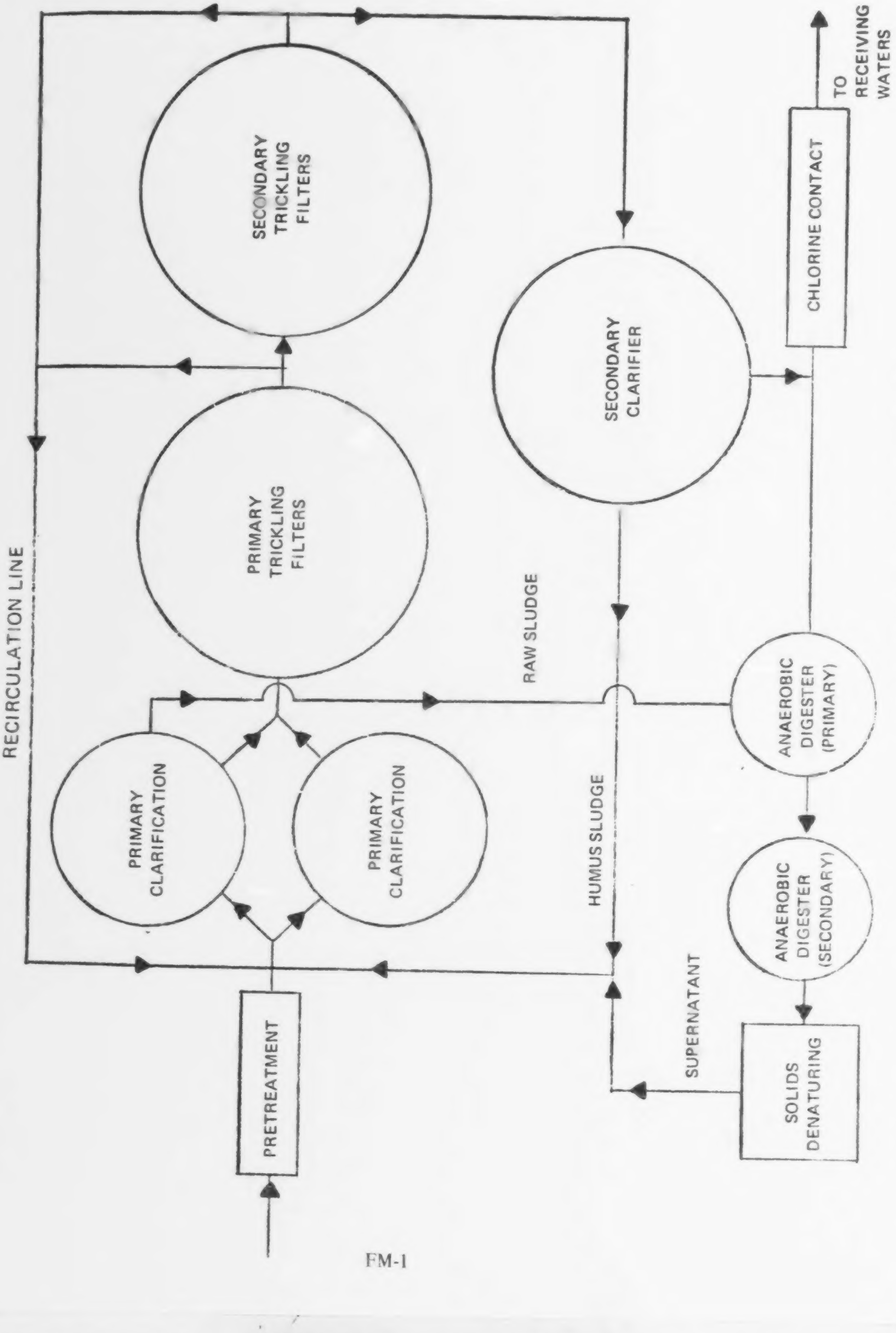
FM 2-11

LESSON: FLOW MEASUREMENT

Index of Notebook Materials

PAGE	MATERIAL	USE IN LESSON
FM – 1	Trickling Filter Flow Diagram	Subdivision 1, Section III Used as basis for student problem
FM – 2, 3	Answer Sheets, Problems on Measuring Flow Volumes	Used by student groups to complete student problem solving exercises, Subdivision 1, Section III
FM – 4, 5	Flow Measurement Troubleshooting Guide	Subdivision 2, Section III, Brief presentation of outline by instructor
FM – 6	Flow Equations and Discharge Formulae	Subdivision 2, Section IV, Referred by instructor
FM – 7	References	

DESIGN FLOW: 10 MGD


RECIRCULATION LINE
SECONDARY TRICKLING FILTERS
PRIMARY TRICKLING FILTERS
PRIMARY CLARIFICATION
PRIMARY CLARIFICATION
PRETREATMENT
RAW SLUDGE
HUMUS SLUDGE
SECONDARY CLARIFIER
CHLORINE CONTACT
TO RECEIVING WATERS
ANAEROBIC DIGESTER (PRIMARY)
ANAEROBIC DIGESTER (SECONDARY)
SUPERNATANT
SOLIDS DENATURING

TRICKLING FILTER FLOW DIAGRAM

GROUP ______________________ **ANSWER SHEET – Page 1**

MEASURING FLOW VOLUMES – IMPACT ON PLANT OPERATIONS

1. Using the Trickling Filter Flow Diagram, identify the following major plant flows by numbering key points on the flow diagram according to the type of flow, as follows:

   1. Influent flows

   2a. Internal flows – parallel distribution

   2b. Internal flows – series distribution

   3. Side streams (sludge, supernatant, etc)

   4. Chemical feeds – actual or possible

   5. Effluent

2. For each of the following processes, determine whether plant performance would be affected by the operator's inability to accurately measure flow volumes identified in question 1.

	Process	**Yes or No Performance Affected**	**Possible Indicators of Poor Performance**
a.	Pretreatment		
b.	Primary Clarification		
c.	Trickling Filter		

GROUP ______________________

Measuring Flow Volumes – Impact on Plant Operations – Continued

Process	Yes or No Performance Affected	Possible Indicators of Poor Performance
d. Secondary Clarifier		
e. Digesters		
f. Chlorination		
g. Effluent Quality		

3. For each flow identified in Question 1, identify a flow measurement device that would normally be used

FLOW MEASUREMENT TROUBLESHOOTING GUIDE

Note: This is presented as a systematic guide to students for troubleshooting flow measurement problems at treatment plants.

I. Analyze Plant Flow Measurement Capability

  A. Review plans and flow diagrams

    1. Define plant processes, operations, and sub-systems
    2. Locate sources and discharge points of all streams and side streams
    3. Study plant flexibility with respect to possible mode change
    4. Locate measuring devices and evaluate their adequacy with respect to:
      a. type of device used
      b. location
      c. size
      d. recording and totalling capability
      e. overall installation

  B. Tour facility

    1. Observe physical layout and location of measuring devices, valves, pumps and tanks
    2. Discuss plant performance with operator, plant personnel
    3. Seek the opinions of plant personnel
    4. Learn color coding, labeling and unit designations
    5. Examine measuring devices, their installation and condition

  C. Examine flow charts

    1. Evaluate trends
    2. Check for storm response
    3. Identify unusual deviations

  D. Study manufacturer's recommendations for user maintenance

    1. Review maintenance records

  E. Examine instrumentation

    1. Check for evidence of operator tampering

  F. Inspect weirs and flumes

    1. Measure appropriate heads
    2. Check instrument readings
    3. Check for obstructions, turbulence and condition of device
    4. Disturb floats, check for response on flow charts
    5. Observe surge action

II. Formulate Alternatives

A. Possible causes to plant problems

1. Poor control over specific treatment processes
2. Organic overloading
3. Poor management and administration
-
-

n. Difficulties or inaccuracies in measuring flows

B. Prioritize alternatives and corrective actions

C. Confirm opinion if possible

D. Get outside help if necessary

E. There may not be one single "right" answer

III. Take appropriate corrective actions, observe and test. With regard to flow measurement problems, this may mean –

A. Major Corrective Action

1. Install metering equipment at points where flow data is necessary
2. Repair existing flow measurement systems
3. Calibrate existing flow measurement systems
4. Modify or replace systems for transmitting, recording or totalling flow data
5. Correct faulty installations, and conditions which cause flow measurement devices to operate improperly
6. Cleaning and preventive maintenance
7. Develop accurate charts
8. Install counters and timers on pumps

B. Expedient Actions on a Temporary Basis – Until Permanent Improvement Can be Made

1. Improve or "fix-up" present systems
2. Install temporary recorders
3. Calibrate existing devices
4. Install devices to facilitate quick measurements in the future
5. Install temporary measuring systems
6. Calculate flows from pipe or channel measurements
7. Compute flows using pump curves

C. Flow balancing and equalization within the plant

1. Equalize flows to parallel plant units
2. Increase or decrease flows where necessary for process control
3. Balance solid loadings by using centrifuge
4. Modify chemical feed rates

DISCHARGE FORMULAE*

1. Basic Flow Formula $Q = AV$
2. Mannings Formula $V = \frac{1.486}{n} R^{2/3} S^{1/2}$ (Flow in pipes)
3. 90° V-notch weir $Q = 2.52\ H^{2.47}$ cfs
4. 60° V-notch weir $Q = 1.43\ H^{2.5}$ cfs
5. Proportional weir $Q = 7.87\ mH$ cfs
6. Rectangular weir $Q = 3.33\ LH^{1.5}$ cfs
7. Cippoletti weir $Q = 3.367\ LH^{1.5}$ cfs (trapezoidal)
8. Parshall Flume $Q = 4\ WH_a^{1.522W^{0.026}}$ cfs
9. Venturi meter $Q = \frac{C_v \pi d_2^2}{4} \sqrt{\frac{2gh}{1 - \left(\frac{d_2}{d_1}\right)^4}}$
10. Orifice $Q = C_d A \sqrt{2gH}$
11. Parabolic flume } Calibrated by
12. Magnetic meter } manufacturer
13. California Pipe Method }
14. Board of Water Engineers Method } nomographs
15. Volume Displacement Method

Q = flow
A = cross sectional area
V = velocity
n = roughness coef
R = hydraulic radius
S = slope
H, h = head
m = width at the point where H = 1 ft

L = length
W = throat width
C_v = velocity coef
g = gravity constant (32.2)
d = diameter of pipe
C_d = discharge coef

*Courtesy of the Texas Water Quality Board, Austin, Texas

REFERENCES – FLOW MEASUREMENT

URS Research Company. Procedural Manual for Evaluating Performance of Wastewater Treatment Plants. Environmental Protection Agency.

The Texas Water Utilities Association. Manual of Wastewater Operations. 1971.

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Leopold Stevens, Inc. Hydrographic Data Book, 8th Edition. P.O. Box 25347, Portland, Oregon 97225.

Manning Environmental Corporation. Flow Tables for Circular Pipes. 112 Dakota Avenue, Santa Cruz, California 95060.

King, W.K., and E.F. Brater. Handbook of Hydraulics, 5th Edition. McGraw-Hill, New York. 1963.

Davis, D.V., and D.E. Sorensen. Handbook of Applied Hydraulics, 3rd Edition. McGraw-Hill, New York. 1969.

Bauer, S.W., and W.H. Graf. Free Overfall as Flow Measuring Device. In Proceedings: American Society of Civil Engineers, Journal, Irrigation Drainage Division, 97 IR, 7987. 1971.

National Bureau of Standards, U.S. Department of Commerce. A Guide to Methods and Standards for the Measurement of Water Flow. 1975.

Office of Research and Monitoring, U.S. EPA. Flow Augmenting Effects of Additives on Open Channel Flows. Environmental Protection Technology Series, EPA-R2-83-238, Washington, D.C. 20460. 1973.

LESSON – CHEMICAL ADDITIONS

Instructor Overview of Lesson

Entry Level Behavior: Students will have had University training in Sanitary Engineering, waste treatment and/or related sciences or equivalent in experience and training. Some field experience in inspecting treatment plants, but none in operating waste treatment facilities.

As a preprequisite to this course, it is recommended that the student will be able to –

1. Identify treatment plant process units.
2. Describe treatment plant process units and equipment in technical terms.
3. Identify and explain the purpose of components of treatment plant process units, how they work and why they are important to the overall process.
4. Describe the normal operating procedures for treatment plant process unit components.
5. Identify when treatment plant process units are not operating properly

Instructor Objectives: The principal instructor objectives for this lesson are:

1. To introduce the topic of chemical additions to treatment plants to upgrade performance.
2. To provide state and federal field personnel with sufficient information that they may be able to recognize the applicability of chemical additions to plants that they visit.
3. To stress the use of the Process of Troubleshooting in solving operational problems with chemical additions.

References: Note list of references included with Student Notebook materials.

Total Length of Lesson: 2 Subdivisions, 1 hour.

LESSON OVERVIEW

Subdivision Title & Time	Major Student Objectives	Key Points & Content	Approach	Materials
1. Using chemicals to Upgrade Treatment Plants. 40 Minutes	1. List & Describe purposes and benefits of chemical additions.	1. Purpose of chemical additions.	1. Follow subject outline. Use prepared slide series. Use student notebook materials at appropriate points in the lesson. Encourage student discussion and questions.	1. Slide series and slide key.
	2. Describe tests, including jar tests, needed to determine proper chemicals and doses.	2. Impact of chemical additions.		2. Student notebook pages CA 1-15.
	3. Recognize factors in considering chemical additions.	3. Determining proper chemicals and doses.		
	4. Know the impacts of chemical additions on a conventional plant.	4. Factors considered in applying chemicals.		
		5. Consequences on plant of Chemical Additives.		
2. Troubleshooting Plants with Chemical Additions. 20 Minutes	1. List and identify trouble indicators in operations using chemical additions.	1. Troubleshooters must be experienced with chemical additions if they are to assist.	1. Follow subject outline. Use prepared slides. Emphasize Process of Troubleshooting.	1. Slide series & slide key.
	2. Know which observations and tests to use in troubleshooting chemical additions.	2. The systematic Process of Troubleshooting is particularly important.		2. Process of Troubleshooting Chart.
	3. Determine alternative corrections for problems with chemical additions.	3. Troubleshooters must know the expected plant performance.		

LESSON – CHEMICAL ADDITIONS

Presentation Options for Course Director

The 60 minute lesson, CHEMICAL ADDITIONS, is one of the less essential lessons of this course. It is included because the course developers believe that troubleshooters will, in the future, increasingly confront such plants and will be in a position to provide needed technical assistance. In areas where it is not likely to be useful to field personnel, this lesson may be excluded from the course.

Major expansions of the lesson would be possible, if desired, and if time permitted. However, additional course material would be necessary. Subjects covered in the lesson which could be expanded include:

Subdivision 1 – Using Chemicals to Upgrade Treatment Plants:

IIC – Aids to Secondary Treatment. This is one area where the instructor could go into great depth.

III – Determining Proper Chemicals and Their Doses.

IV – Applying Chemicals – Chemical feed equipment could be studied in detail for troubleshooting purposes.

For an overall course presentation of between 28 and 40 hours, it is recommended that this lesson be kept at one hour, without expanding its scope.

If this topic is of great importance to the particular student group, and if time permits, the lesson could be taught at a slower pace over a 90 minute or 2 hour time period. If this is done, every effort should be made to increase student discussion and participation in the lesson.

Lesson Plan – Subdivision 1 **Time: 40 Minutes**

Title: Using Chemicals to Upgrade Treatment Plants

Instructor Objectives: To introduce the topic of chemical additions to treatment plants to upgrade performance. To provide state and federal field personnel with sufficient background and information on chemical additions that they may be able to recognize the application of chemical additions to plants that they visit.

Student Objectives: As a result of this lesson subdivision, students will be able to do the following:

1. List the purposes and uses of chemical additives to upgrade conventional sewage treatment plants.
2. Describe the removal benefits obtained from using chemical additives.
3. Identify tests that need to be performed in determining proper chemicals and their doses.
4. Recognize the need for jar tests and understand the general principles of carrying out a jar test.
5. Identify chemicals generally used as coagulants and as aids to coagulation.
6. Recognize the factors which need to be considered in applying chemicals in a treatment plant, and take those factors into consideration while evaluating the potential for chemical additions at a treatment plant.
7. Identify and describe chemical feed systems for applying coagulants in treatment plants.
8. List the advantages of applying chemicals to sewage treatment plants.
9. List the disadvantages of applying chemicals to sewage treatment plants.
10. Recognize some of the maintenance and safety problems inherent in using chemical additives at treatment plants.

Training Materials:

Slide series with slide key, and index of picture slides.

Student Notebook section on Chemical Additions, including:

Pages CA 1-3	Tables on the effectiveness of chemicals.
CA 4-5	Example 1 – Determining Chemical Dosage: Jar Test.
CA 6	Coagulation of Raw Sewage with Alum.
CA 7-14	Diagrams of Chemical Feed Systems.
CA 15	List of types of chemical feeders.

Classroom Set-Up:

A normal classroom set-up will be required. Students should be seated with their student groups.

35 mm Carousel slide projector with remote controls

Large screen (8 ft x 10 ft)

Chalkboard or easel

Pointer

Subdivision Schedule:

Within the 40 minute time period, the following schedule should be observed in presenting the lesson plan outline.

TIME	SUBJECT
0 – 5 Minutes	Purpose and use of chemical additives
5 – 10 Minutes	Impact of chemical additives
10 – 20 Minutes	Determining proper chemicals and their doses
20 – 30 Minutes	Applying chemicals
30 – 40 Minutes	Consequences on plant of chemical additives

Subdivision Approach

The instructor is to rely upon the lesson outline, and particularly upon the slide series and slide key.

Student Notebooks are to be used by instructor by having students turn to the appropriate pages at the appropriate point in the lesson.

Example 1 – Typical jar test result, in Student Notebook, is to be discussed by students and instructor.

Student discussion and questions are to be encouraged. Reference should be made by the instructor to the use of chemicals for plant upgrading and solving operational problems, whenever possible.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
I. Purpose and use of chemical additives for plant upgrading (5 minutes) Use sequence of word slides as follows:	Instructor should make comments appropriate to each slide.
A. "PURPOSE OF CHEMICAL ADDITIVES TO CONVENTIONAL PLANTS" • To improve clarification through coagulation • Phosphorus removal	SLIDE CA-1 (word) Introduction to section. Do students know of other purposes?
B. "SITUATIONS WHERE COAGULANTS OR COAGULANT AIDS MAY BE EFFECTIVE" • High flow rates in useable clarifiers • Control of pollutant dumps • Performance upsets	SLIDE CA-2 (word) Principal uses of coagulants to improve clarification.
C. "USES OF COAGULANTS – HIGH FLOW RATES" • Excessive rainfall or drainage • Clarifier outage • Seasonal industrial loads • Peak loading, daily or special events	SLIDE CA-3 (word) Key Point: These uses can usually be planned for.
D. "USES OF COAGULANTS – CONTROL OF POLLUTANT DUMPS" • Septage • Industrial commercial dumps • Accidental spills • Excessive return flows	SLIDE CA-4 (word) Key Point: These uses must be made immediately upon identifying a problem. If chemicals are to be effective when there is a sudden load, the operator must be quick.
E. "USES OF COAGULANTS – PERFORMANCE UPSETS" • Slow settling activated sludge • Shock or toxic loadings • Aeration inadequacy • Poor process controls	SLIDE CA-5 (word) Key Point: These uses generally are alternatives to other process controls.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
F. "CHEMICAL ADDITIVES MAY BE USED TO" • Solve temporary operating or loading problems • Temporarily upgrade pending plant modification or expansion • Permanently upgrade performance and effluent quality	SLIDE CA-6 (word) Key Point: Note how chemicals may be used to achieve a variety of treatment objectives.
G. "SOME ALTERNATIVES TO CHEMICALS" • Flow reduction or equalization • Preaeration • Prechlorination • Fine tune process controls • Expand or modify plant	SLIDE CA-7 (word) Key Point: Alternatives should always be considered. Many may be less costly, or less difficult to implement.
II. Impact of Chemical Additives (5 Minutes) A. Removal Efficiencies 1. Vary by plant, process, chemicals used, etc. 2. Generally results in substantial improvement in clarifier performance and removal of phosphorus	
B. "REMOVALS" • SS – increase from 50% to 80% • BOD – increase from 30% to 60% • metals which inhibit secondary treatment • up to 95% of phosphorus	SLIDE CA-8 (word) Guide: This gives a picture of what can be expected.
C. "AIDS TO SECONDARY TREATMENT" • Activated sludge: Chemicals increase settling rate in secondary clarifier • Trickling filter: Chemicals enhance settling during overloaded or septic conditions • Lagoons: Chemicals settle solids during periods of upset	SLIDE CA-9 (word) Key Point: Uses of chemicals in secondary treatment.
D. Specific results obtained – refer students to tables reproduced in Student Notebook	Refer to Tables on pages CA-1 – CA-3. Key Point: Effectiveness of chemicals, variability of results.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
III. Determining Proper Chemicals and Their Doses (10 Minutes)	
A. In using chemical additives, tests must be made to determine: 1. Which polymer or chemical to use 2. pH at which additive is most effective 3. Dose of additive 4. Mixing time and characteristics 5. Resulting removals of: a. suspended solids b. turbidity c. phosphorus	Key Point: Stress the importance of testing for chemical use.
B. Method of testing chemical additions – jar test.	Show picture slide CA-10*
C. Typical jar test result. Have class groups look over Example 1 to review the elements of a typical jar test, and the jar test results on page CA-5. Discuss jar test results with class.	Refer class to Student Notebook, Example 1 – pages CA-4, CA-5. *For more details on picture slides – refer to slide index following this outline.
D. Chemicals Commonly Used.	For more information, refer students to Chapter 5, EPA Technology Transfer Process Design Manual for Suspended Solids Removal.
1. "ALUM (Aluminum Sulfate)" • available in dry and liquid form • normally requires added alkalinity by - hydrated lime – $Ca(H)_2$ - alkalinity – $CaCO_3$ - soda ash – Na_2CO_3	SLIDE CA-11 (word) Refer to Student Notebook page CA-6 Turbidity removal by Alum.
2. "IRON COMPOUNDS" • liquid Ferric Chloride – $FeCl_3$ • waste Pickle Liquor – $FeCl_2$ - available from steel plants • Ferric Sulfate – $Fe_2(SO_4)_3$ • Ferrous Sulfate – $FeSO_4$ • normally requires alkalinity	SLIDE CA-12 (word) Guide: These are commonly used iron compounds

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
3. "LIME" • Quicklime – CaO • Hydrated lime – $Ca(OH)_2$	SLIDE CA-13 (word)
4. "OTHER INORGANIC CHEMICALS" • soda ash – Na_2CO_3 • liquid caustic soda – NaOH • carbon dioxide – CO_2	SLIDE CA-14 (word) Guide: There are other chemicals that may be used.
5. "POLYMERS – POLYELECTROLYTES" • come in dry or liquid form • plus charge – cationic • negative charge – anionic • no charge – nonionic	SLIDE CA-15 (word) Guide: Nature of polymer choices.
6. "USE OF POLYMERS – FACTORS TO BE CONSIDERED" • size, density and charge of colloids to be coagulated • pH • coagulants used • feeding and mixing • jar testing and plant-scale testing is a must!	SLIDE CA-16 (word) Key Point: Polymer selection requires careful testing.
IV. Applying Chemicals (10 Minutes) A. "FACTORS IN APPLYING CHEMICALS" • Chemical storage facilities • Mixing equipment • Dosing equipment • Point of introduction • Distribution piping • Protected storage and working areas • Laboratory • Capable staff	Use slide CA-17 (word) as an introduction to this section. Keep slide on screen while discussing this material.
B. Chemical storage facilities 1. Volume and type depend upon type of chemical, amount, supply and shipping arrangements 2. Chemicals in solution a. simplify mixing and dosing b. often corrosive – require tankage protected from corrosion	Discuss each factor with class.

LESSON OVERVIEW

3. Dry Chemicals
   a. lower shipping costs
   b. more costly to mix and handle

C. Mixing
1. Needed for dry chemicals
2. Should be sufficient for 1 to 3 days supply
3. Without adequate mixing, polyelectrolytes form viscouse masses and non-uniform solution
4. Must use adequate energy for mixing
5. Undermixing –
   a. Results in uneven dosing
   b. Reduces efficiency of solids removal
   c. Requires unnecessarily high coagulant doses
6. Overmixing
   a. Disperses newly formed floc
   b. Increases flocculation period
   c. Ruptures existing wastewater solids – thus bringing less efficient removal

D. Dosing
1. Can be simple or elaborate, depending on situation
2. Powdered chemicals – small doses
   a. can be sprinkled over tank or inlet channel
3. Solution feeders – sample
   a. rubber tube siphon and pinch clamp
4. Dry feeders – can provide uniform feed rate at higher dosages
5. Solution feeders – chemically resistant
   a. adjustable dosage control
   b. sufficient head pressure if feeds into tank bottom or closed conduit

E. Point of Introduction
1. Into any point of high mixing energy, such as open channel, pump inlet, eye of aerator, flash mix chamber
2. Monitor floc formation and coagulant use

KEY POINTS & INSTRUCTOR GUIDE

Following Section D refer students to pages CA-7 thru CA-15, Student Notebook – on Chemical Feed Systems. Briefly go thru each type of system.

(Delete if instructor is running behind in time.)

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

F. Distribution Piping
  1. Allows for optional introduction points in fixed systems
  2. Use screens to prevent trash or lumps from flowing through
  3. Should be corrosion resistant
  4. Provide for cleanout and flushing

G. Protected Areas — necessary in many cases to provide protection from weather

H. Laboratory — needed for jar testing, monitoring of effluent quality, etc.

I. Capable Staff — needed for added functions created by chemical additions, including:
  1. Monitoring and process control
  2. Sampling and jar testing
  3. Cleanup, maintenance and sludge handling

V. Total Consequences on Plant of Chemical Additives (10 Minutes)

Key Point: Stress that chemical additions have both advantages and disadvantages that need to be considered.

A. Advantages
  1. Relieve severely stressed secondary treatment systems
  2. Increase removal efficiencies
  3. "Buy time" for plant until major modifications can be made
  4. Handle high peak loadings or upsets

B. Some disadvantages of chemical additives

"DISADVANTAGES TO CHEMICAL ADDITIVES"

SLIDE CA-18 (word)

- Cost — chemicals, equipment, energy, sludge disposal
- Larger volumes of sludge to handle
- Requires more process control and monitoring
- Requires more sampling and testing
- Additional maintenance
- Additional safety hazard

Show slides CA-19 thru CA-27 on Maintenance and safety factors. For more details on picture slides refer to slide index on CA 1-10.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
All slides were taken at the Rosemount Advanced Waste Treatment Plant, Rosemount, Minnesota, 1975	Note on slides:
1. Maintenance	
a. Maintenance of pH monitor for chemical feed.	
When an acid neutralization step is involved in the process, automated pH control may be used. The main problem associated with this type of control is to maintain accurate pH measurements. The pH system should be checked a minimum of once each day until it proves to be reliable for longer periods. Electrode cleaning may be required on a daily basis.	
1. Debris from pH control box	SLIDE CA-19
2. Cleaning electrodes with dilute HCL	SLIDE CA-20
b. Monitoring chemical feed Operator checking drawdown on 5 gal. carboy installed to calibrate pumps feeding ferric chloride solution. Liquid ferric chloride storage tank in background.	SLIDE CA-21
c. Lime Feed Maintenance	
1. Lime feed pumps with check valves exposed – lime deposits	SLIDE CA-22
2. Check valve prior to cleaning – valves do not seat because of small pebbles and lime deposits	SLIDE CA-23
3. Clean check valve	SLIDE CA-24
2. Safety hazards increase when chemicals are introduced at a plant. Precautions must be taken.	
a. Eye wash near chemical feed pumps	SLIDE CA-25
b. Shower near chemical feed pumps	SLIDE CA-26
c. Likewise, precautions must be taken against the possibility of dangerous fumes	SLIDE CA-27
C. Other Chemicals: Plant operators have been tempted by salesmen making claims for other chemicals as "miracle" ingredients to solve problems at treatment plants. Such chemicals include:	
1. Masking agents – to mask plant odors	
2. Enzymes – to "improve" biological treatment	
3. There is no evidence as to the value of these chemicals, and troubleshooters should not recommend their use	

INDEX OF PICTURE SLIDES

Chemical Additions Lesson **Subdivision 1**

Slide	Time & Place	Content and Purpose
		Note: All slides for this subdivision were taken at the Rosemount Advanced Wastewater Treatment Plant, Rosemount, Minnesota, in 1975. This plant is a complete physical-chemical treatment facility, with no biological treatment processes used. The slides all pertain to the chemical clarification process at the plant, and are appropriate to the discussion of chemical additions to conventional treatment facilities. In addition to chemical clarification, the Rosemount Facility also has filtration and carbon adsorption. The capacity of the plant is 600,000 GPD, normal flow has been 200,000-300,000 GPD.
CA-10	Rosemount, 1975	Typical jar test for coagulants. This was performed by adding ferric chloride to raw sewage, rapid mix for 15 minutes, then slow mix.
CA-19	Rosemount, 1975	Shows required maintenance on the automated pH control.
CA-20	Rosemount, 1975	Electrodes in pH control box, which may require cleaning daily.
CA-21	Rosemount, 1975	Operator checking drawdown on 5 gal carboy installed to calibrate pumps feeding ferric chloride solution. Liquid ferric chloride storage tank in background.
CA-22	Rosemount, 1975	Shows heavy lime deposits on check valves — line from lime feed pumps. Example of a facet of chemical additions that requires constant maintenance.
CA-23 CA-24	Rosemount, 1975	Same valve — before and after cleaning.
CA-25	Rosemount, 1975	Shows an eye wash located near the chemical feed pumps, an important safety precaution.
CA-26	Rosemount, 1975	Likewise, shows an emergency shower located near chemical feed pumps.
CA-27	Rosemount, 1975	Shows emergency breathing equipment, located throughout the plant as a precaution.

Lesson Plan – Subdivision 2 **Time: 20 Minutes**

Title: Troubleshooting Plants with Chemical Additions

Instructor Objectives: To provide for the students the basic elements of the Process of Troubleshooting as it relates to operational problems in adding chemicals to conventional treatment plants. To stress the use of the systematic Process of Troubleshooting as a valuable tool in solving problems.

Student Objectives: As a result of this lesson subdivision, students will be able to do the following:

1. Carefully consider whether or not they are able to assist and solve problems in a plant employing chemical additives.
2. Recognize the elements of the Process of Troubleshooting which are particularly important in problems with chemical additions.
3. List and identify trouble indicators in operations employing chemical additives.
4. Carry out observations for troubleshooting chemical additions.
5. List and conduct tests and analyses for troubleshooting chemical additions.
6. Determine possible alternative corrections for problems involving chemical additions.

Training Materials:

Slide series with slide key
Process of Troubleshooting Chart

Classroom Set-Up:

A normal classroom set-up will be required. Students should be seated with their student groups

35 mm carousel slide projector with remote controls

Large screen (8 ft x 10 ft)

Chalkboard or easel

Pointer

Subdivision Schedule:

Within the 20 minute time period, the following schedule should be observed in presenting the lesson plan outline.

TIME	SUBJECT
0 – 2 Minutes	Basis for troubleshooting chemical additions
2 – 5 Minutes	Process of Troubleshooting
5 – 15 Minutes	Troubleshooting plants with chemical additions
15 – 20 Minutes	Questions and Discussion

Subdivision Approach:

The instructor is to rely upon the lesson outline, using the slide series and slide key.

The Process of Troubleshooting is to be emphasized. All material should be related to the Process and its use in solving operational problems.

LESSON OUTLINE

I. Basis for troubleshooting plants with chemical additions. (2 Minutes)

  A. As chemical additions become more widely used, troubleshooters will have to begin to cope with plants using chemical additions.

    1. Particularly in smaller plants, efficiency of operation may decrease once the plant is past the experimental stage.

  B. Don't attempt to troubleshoot in such situations unless you know what you're doing.

  C. Make sure you have proper information and background on plant.

    1. Know why chemicals are being used in the first place.
    2. Know what performance is expected.
    3. Know under what conditions chemicals are to be applied.

II. Because of the complexity of the chemical reactions involved, and the cause/effect response of chemical reactions to changing parameters, the use of a systematic Process of Troubleshooting is a must. (3 Minutes)

Particularly important elements of the Process of Troubleshooting are:

  A. Reviewing plant information (1b)
  B. Listening to others, and observing (1c)
  C. Analyzing and testing (1e)
  D. Formulating prioritized alternatives (2d)
  E. Confirming opinions (2e)
  F. Observing results and effects (4)
  G. Monitoring results (5b)
  H. Documentation and follow-up (5c)

III. Troubleshooting plants with Chemical Additions (10 minutes)

  A. "KNOW EXPECTED PLANT PERFORMANCE"

    - Removal characteristics
    - pH requirements for chemical reaction
    - Proper performance of all equipment involved
    - Sludge characteristics

KEY POINTS & INSTRUCTOR GUIDE

Key Point: Troubleshooters must be experienced in Chemical Additions, or may have to seek outside help.

Key Point: Process of Troubleshooting is valuable in dealing with problems of Chemical Additions

Numbers in ( ) refer to elements on the chart: THE PROCESS OF TROUBLESHOOTING. Instructor should refer to troubleshooting chart in Student Notebook.

SLIDE CA-28

Key Point: This is an important step in the Troubleshooting Process.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
B. "TROUBLE INDICATORS" • Floating and gaseous sludge in primary clarifiers • Poor sludge settling characteristics • Poor sludge dewatering characteristics • Poor removals of solids or phosphorus	SLIDE CA-29
C. "OBSERVATIONS – FOR TROUBLESHOOTING CHEMICAL ADDITIONS • Dosing sequence of chemicals • Energy in mixing • Flocculation energy • Sludge behavior	**SLIDE CA-30** **Guide: These are the things troubleshooters have to look for**
D. "TESTS AND ANALYSES FOR CHEMICAL ADDITIONS" • Quantity of chemicals used • pH, alkalinity • Jar tests • Effluent quality, solids, BOD, phosphorus	SLIDE CA-31 Key Point: Testing is particularly important.
E. "POSSIBLE ALTERNATIVE CORRECTIONS" • Change dosage of coagulants and alkalinity • Change points of introduction of chemicals • Assure sufficient rapid mix energy • Adjust dosage in line with flow and concentration of inflow	SLIDE CA-32 Guide: These possible troubleshooter recommendations all require considerable knowledge and analyses.
IV. "LESSON SUMMARY – CHEMICAL ADDITIONS" • Chemicals upgrade plant performance • Chemicals require careful analysis • Chemicals add to cost of operation, create secondary effects in plant • Chemicals are more difficult to troubleshoot than conventional operations	SLIDE CA-33 Guide: Keep this slide on the screen while summarizing and completing this this lesson.
V. Questions and Discussion (5 Minutes) Close out this lesson with class discussion and student questions with remaining time.	
At end of lesson, refer students to a three (3) page example provided in Student notebook, pages CA-16 to CA-18. Advise that this will provide them with one example of an interesting application of chemicals to a secondary plant.	Reference: Notebook pages CA-16 thru 18.

STUDENT NOTEBOOK MATERIALS

The following materials are included in the section of the Student Notebook on Chemical Additions. The Notebook is distributed to students at the start of the course, and is available to them as a reference material throughout the course.

Instructors are encouraged to make reference to Student Notebook materials and to have the students use the Notebook where it is an appropriate part of the lesson. Please note specific references in the instructor's lesson plan to Student Notebook materials.

Index of Notebook Materials

Pages	Material	Use in Lesson
CA – 1 thru 3*	Tables on the effect of Chemical Additions	Reference by instructor Subdivision 1, Section II
CA – 4, 5	Example on determining Chemical Dosage, and Typical Jar Test Results	Class is to review the example, and the jar test results. Instructor is to discuss jar test results with class. Subdivision 1, Section III
CA – 6*	Coagulation of Raw Sewage with Alum- graphs	Reference by instructor Subdivision 1, Section III-D
CA – 7 thru 14*	Diagrams of Various Chemical Feed Systems	Reference and brief discussion of each feed system by instructor. Subdivision 1, Section IV-D
CA – 15	Table – Types of Chemical Feeders	Reference by instructor Subdivision 1, Section IV-D
CA – 16 thru 18*	Example: Innovative Plant Personnel and Alum Make Successful Phosphorus Removal Team at Grandville, Michigan	Reference by instructor. To be read by students following lesson. Subdivision 2, Section V
CA – 19 & 20	References	

* Denotes pages reproduced from EPA Manual "Upgrading Existing Wastewater Treatment Plants."

Reproduced from EPA Process Design Manual for Upgrading Existing Wastewater Treatment Plants

EFFECT OF CHEMICAL TREATMENT ON PRIMARY CLARIFIER PERFORMANCE

Type and Amount of Chemical Added	Performance Preceding Chemical Treatment				Weight Ratio of WAS/PS[1]	Performance After Chemical Treatment				Weight Ratio of WAS/PS[1]	Reference
	SS Removed		BOD Removed			SS Removed		BOD Removed			
	mg/l	percent	mg/l	percent		mg/l	percent	mg/l	percent		
Purifloc – A21 (0.95 mg/l)	13	12	28	26	0.61	75	65	46	48	0.31	21
DOW – SA 1193 (0.2 mg/l)	13	12	28	26	0.61	72	55	36	37	0.41	21
Purifloc – A21 (1 mg/l)	157	43	82	23	–	281	76	127	33	–	21
Purifloc – A21 (0.75 mg/l)	26	18	–	–	–	69	52	–	–	–	21
Purifloc – A21 (0.89 mg/l)	113	43	50	22	–	159	60	87	37	–	21
DOW – SA1193 (0.25 mg/l)	120	47	–	–	0.8	151	61	–	–	0.46	21
Purifloc – A21 (1 mg/l)	107	47	135	37	–	169	62	154	46	–	21
$FeCl_2$ + NaOH + Purifloc - A23 (0.3 mg/l)	230	82	111	31	–	379	79	74	39	–	22,23
$FeCl_2$ + NaOH + Purifloc – A23 (0.3 mg/l)	104	49.7	83	43.8	–	173	76.8	105	57.8	–	22,23
Purifloc – A21 (1 mg/l)	–	–	–	–	0.79	–	–	–	–	0.28	24
Purifloc – A23 (0.25 mg/l)	52	31	47	31	1.44	80	51	58	46.4	0.67	25
$FeCl_3$ + Purifloc – A23	93	33	53	34	–	196	74	102	61	–	26
$FeCl_3$ + Purifloc – A23	93	33	53	34	–	213	68	97	53	–	26
Purifloc – A21 (0.74 mg/l)	–	50	–	36	–	–	63	–	45	–	27
Purifloc – A21M (1.14 mg/l)	–	43	–	–	–	–	63	–	–	–	27
$FeCl_3$ (20 mg/l) + Purifloc – A23 (0.3 mg/l)	1	1.3	–	–	–	38	24.4	–	–	–	28
$FeCl_3$(35 mg/l Fe^{3+}) + Purifloc – A23 (0.5 mg/l)	–	–	–	–	–	323	80	249	61	–	29
$FeCl_3$ (15–18 mg/l Fe^{3+}) + Purifloc – A23 (0.5 mg/l)	–	35.5	–	19.1	–	–	63.6	–	54.4	–	30
$FeCl_3$ (10 mg/l Fe^{3+}) + Purifloc – A23 (0.5 mg/l)	–	–	–	–	–	177	74.5	–	–	–	31
$FeCl_3$ (20-25 mg/l Fe^{3+}) + Purifloc – A23 (0.4 mg/l)	–	–	–	–	–	41	74.0	115	57.4	–	32
$FeCl_3$(22 mg/l Fe^{3+}) + Purifloc – A23 (0.5 mg/l)	–	–	–	–	–	61.7	84	226	38	–	33
Alum (15–20 mg/l Al^{3+}) + Purifloc – A23 (0.5 mg/l)	–	–	–	–	–	134.8	70	423.9	32	–	33
Alum (90 mg/l) + Polyelectrolyte (0.4 mg/l)	–	–	–	–	–	157	84	66	61.1	–	34
Alum (110 mg/l) + Polyelectrolyte (0.35 mg/l)	–	–	–	–	–	204	74	126	71	–	35

[1] WAS – Waste activated sludge
PS – Primary sludge

Reproduced from EPA Process Design Manual for
Upgrading Existing Wastewater Treatment Plants

POLYELECTROLYTE ADDITION TO PRIMARY CLARIFIERS

Treatment Process	Coagulant	Dose	Primary Clarifier				Total Plant				Reference
			Percent Removal Before Poly-electrolyte Addition		Percent Removal After Poly-electrolyte Addition		Percent Removal Before Poly-electrolyte Addition		Percent Removal After Poly-electrolyte Addition		
		mg/l	BOD	SS	BOD	SS	BOD	SS	BOD	SS	
Activated Sludge	Purifloc A-21	1	26	–	48	–	83	–	90	–	37
Trickling Filter	Purifloc A-21	1	23	43	33	76	79	72	85	84	37
Activated Sludge[1]	Purifloc A-23	0.21	31	31	46	51	79	85	83	89	38

LIME ADDITION TO PRIMARY CLARIFIERS

Location	Lime Added	Percent Removal in Primary Before Lime Addition		Percent Removal in Primary After Lime Addition		Remarks	Reference
	mg/l CaO	BOD	SS	BOD	SS		
Duluth, Minnesota	75	50	70	60	75	–	18
	125	55	70	75	90	–	
Rochester, New York	100	–	–	50	80-90	Jar tests	18
Lebanon, Ohio	145	–	–	66	74	Pilot plant	40
Richmond Hill, Ontario	175	21	37	71	77	Full-scale plant	41
Central Contra Costa, Calif.	378	46	71	74	79	Full-scale test	42
	303	37	71	69	76	Full-scale test	

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[1] Case history presented in Chapter 13.

Reproduced from EPA Process Design Manual for
Upgrading Existing Wastewater Treatment Plants

EFFECT OF CHEMICAL TREATMENT ON SECONDARY CLARIFIER PERFORMANCE

Location	Type of Plant	Location of Chemical Addition	Chemical and Dosage	Effluent BOD_5 (or COD) Before Chemical Addition mg/l	Effluent SS Before Chemical Addition mg/l	Effluent BOD_5 (or COD) After Chemical Addition mg/l	Effluent SS After Chemical Addition mg/l	Total Phos. Removal percent	Reference
Richardson, Texas	Trickling filter std. rate	Before final settling	Al/P Mole Dosage 1.6/1	20	15	<5	< 7	95	44
Chapel Hill, North Carolina	Trickling filter high rate	Before final settling	Al/P Mole Dosage 1.6/1	44	64	15	34	82	45
Pennsylvania State	Conventional activated sludge	Aerator effluent	Al/P wt. Ratio 3/1	13	26	9	22	86	46
Cincinnati, Ohio	Activated sludge (100 gpd pilot)	Aerator	10 mg/l Al^{3+}	(89%)[1]	(95%)[1]	(92%)[1]	(96%)[1]	94	47
Lebanon, Ohio	Activated sludge (0.11 mgd pilot)	Final clarifier	Add lime to raise pH=9.4-10.9	--	43.5	--	16.5	--	48
Minneapolis, Minnesota	Trickling filter low rate	Before final settling	720 mg/l $Ca(OH)_2$	83	--	27	--	86	49
Madison, Wisconsin	--	Before final settling	200 mg/l Alum	8-29	--	1.8-2.9	--	98.7	50
University Park, Pennsylvania	Trickling filter	Before final settling	160 mg/l Alum	18	31	6	19	96.4	51
			46 mg/l $Na_2Al_2O_4$	61	95	23	8	93.4	
Bloomington, Illinois	Activated sludge	Aerator	33.9 mg/l Fe^{3+} +0.7 mg/l Purifloc – A23	8.8	12.7	5.0	8.6	--	50
	Trickling filter	Before final settling	25-30 mg/l Fe^{3+} +0.5 mg/l Purifloc – A23	13.0	49.6	3.3	16.0	--	50
Blue Plains,[2] Washington, D.C.	Modified Activated sludge	Before final settling	26 mg/l Alum	47	48	40	43	--	52
			50 mg/l Alum	38	39	27	36	--	
			60 mg/l Alum	68	53	25	36	--	
			80 mg/l Alum	46	41	41	31	--	
			89 mg/l Alum	50	57	30	31	--	
Sandusky, Ohio	Conventional activated sludge	Aerator	50 mg/l Alum	9	24	2	15	80	35
Michigan City, Indiana	Conventional activated sludge	Aerator	60 mg/l Alum	13	19	9	7	92.2	35
Guelph, Ontario	Conventional activated sludge	Aerator	100 mg/l Alum	26	38	14	22	87	35
Palmetto, Florida	Trickling filter	Before final settling	45 mg/l Alum	--	30-40	--	10	--	35

[1] Percent removal.

[2] Data are monthly average.

CHEMICAL ADDITIVES

EXAMPLE 1 – DETERMINING CHEMICAL DOSAGE: JAR TEST

For any given treatment system there are a large number of coagulants and combinations of coagulants and coagulant aids (polymers) that can be used to obtain the required effluent quality. The difficult task is to identify those combinations that are best in terms of economics and other considerations. Other considerations being: sludge volume and dewatering characteristics, chemical delivery times and storage requirements, hazards associated with some materials, and so forth.

Chemical dosages required can be estimated in the laboratory using standard jar testing apparatus. The jar test procedure used should be designed to simulate, as close as possible, the chemical addition and mixing conditions found in the full scale process. The test will generally follow the scheme outlined below:

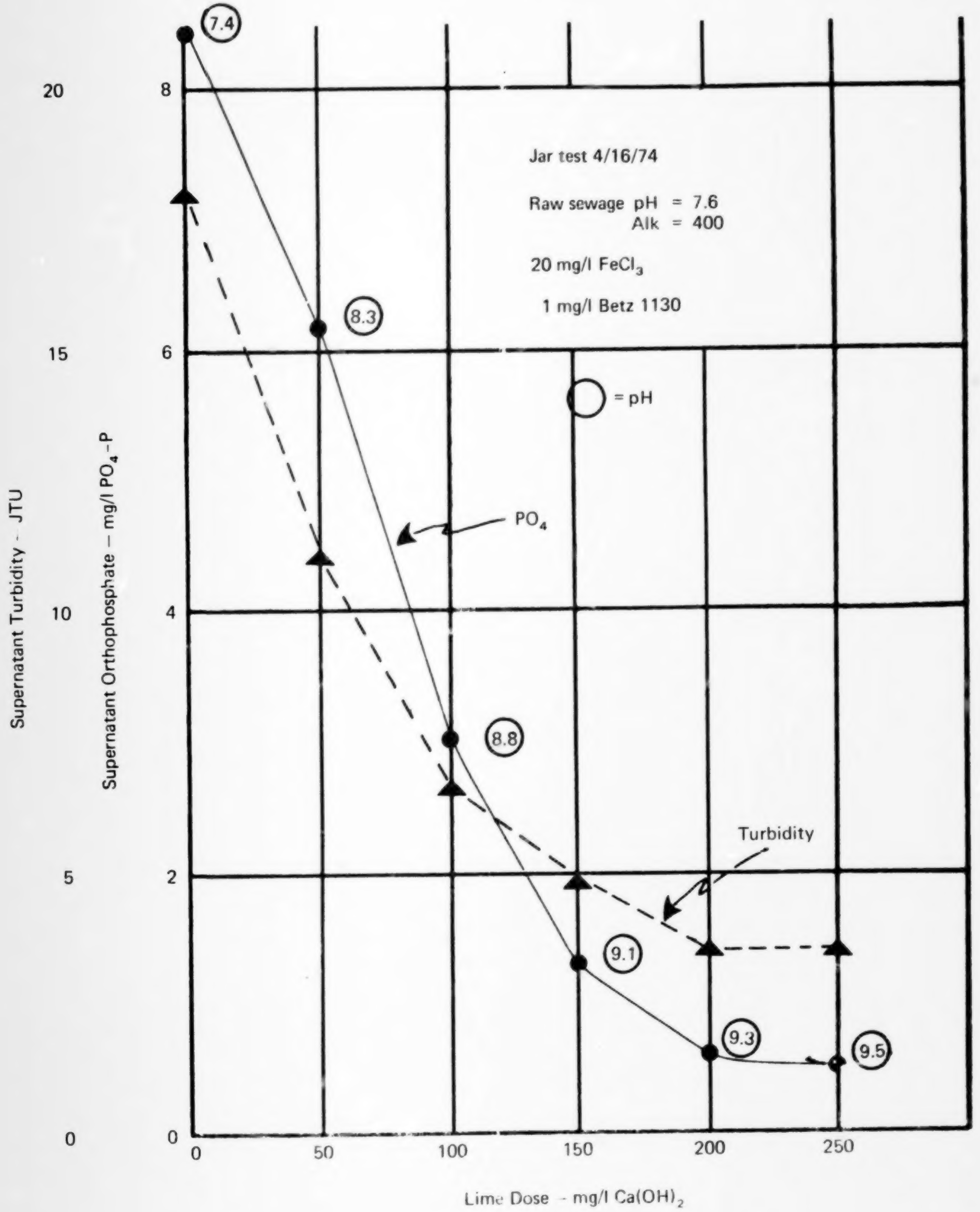
1. Coagulant addition and rapid mix for 15-60 sec. (100 rpm)
2. Slow mix for 5-30 min. (20-30 rpm)
3. Add polymer and continue slow mix 5-10 min.
4. Settle 10-60 min.
5. Sample for analyses

The results of a typical jar test are presented in Figure 1, page CA-5. The test was conducted to observe the effect of lime dose (pH) on phosphorus and turbidity removals when used with ferric chloride and polymer. The test procedure was:

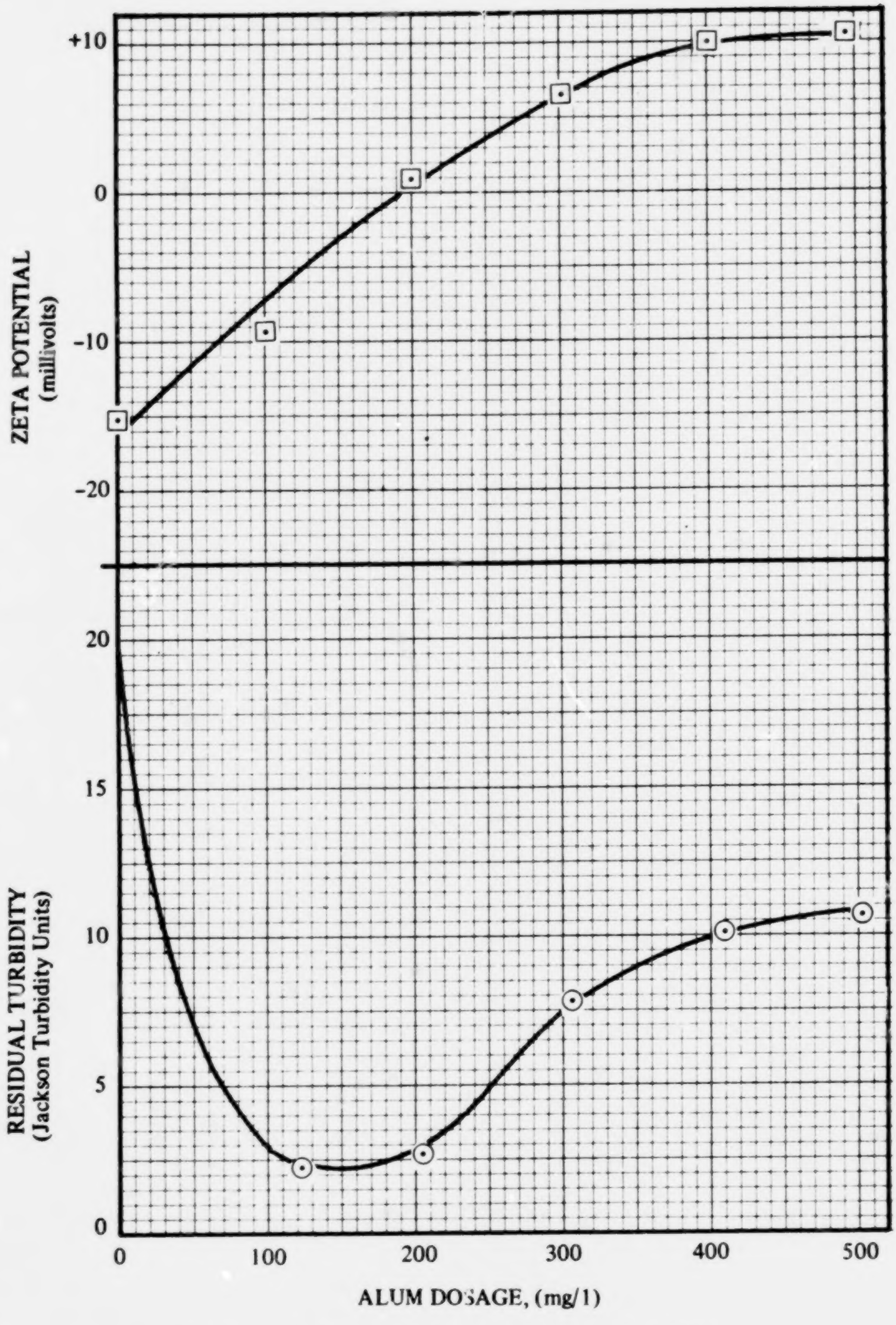
1. Fill 6 jars with 1 liter raw sewage each
2. Add lime and rapid mix for 5 minutes at 100 rpm
3. Add ferric chloride and rapid mix for 1 minute at 100 rpm
4. Mix at 50 rpm for 1 minute
5. Add polymer and mix for 1 minute at 50 rpm
6. Slow mix for 15 minutes at 25 rpm
7. Settle for 25 minutes
8. Sample Supernatant

The raw sewage characteristics were:

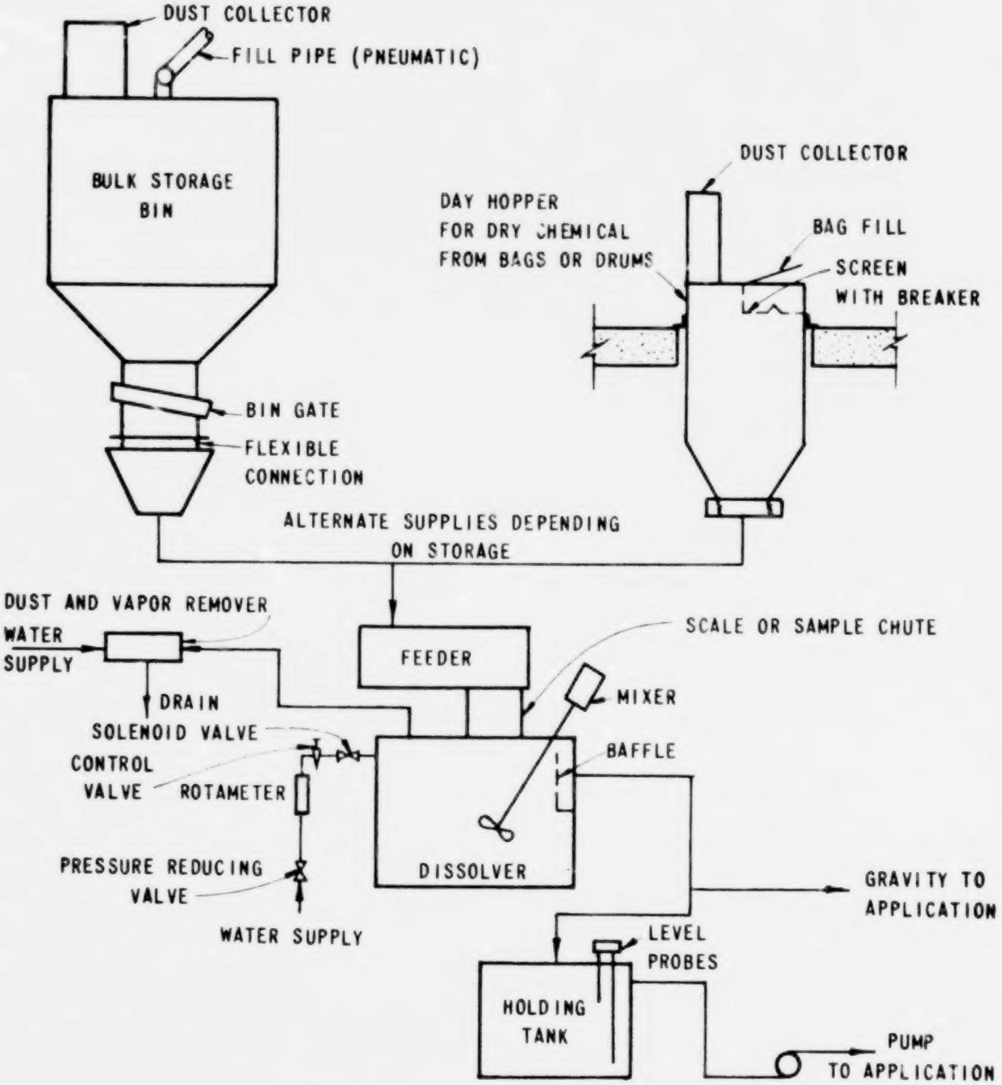
pH = 7.6
Alkalinity = 400 mg/l as $CaCO_3$
PO_4-P = 10.8 mg/l



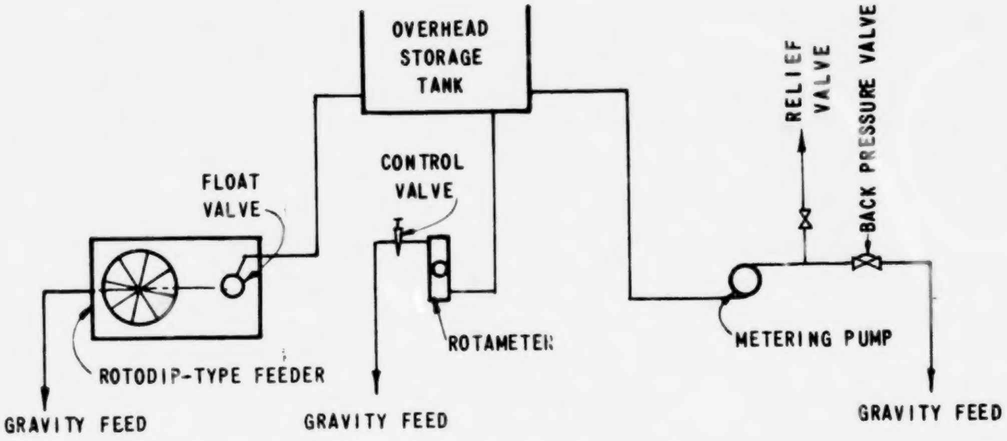
TYPICAL JAR TEST RESULTS



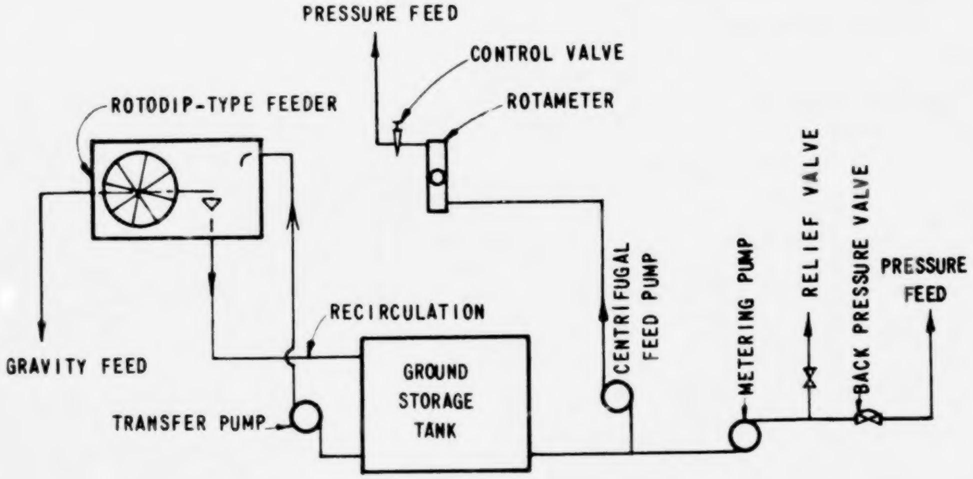
COAGULATION OF RAW SEWAGE WITH ALUM


DUST COLLECTOR
FILL PIPE (PNEUMATIC)
BULK STORAGE BIN
BIN GATE
FLEXIBLE CONNECTION
DUST COLLECTOR
DAY HOPPER FOR DRY CHEMICAL FROM BAGS OR DRUMS
BAG FILL
SCREEN WITH BREAKER
ALTERNATE SUPPLIES DEPENDING ON STORAGE
DUST AND VAPOR REMOVER
WATER SUPPLY
DRAIN
FEEDER
SCALE OR SAMPLE CHUTE
MIXER
SOLENOID VALVE
CONTROL VALVE
ROTAMETER
BAFFLE
DISSOLVER
PRESSURE REDUCING VALVE
WATER SUPPLY
GRAVITY TO APPLICATION
LEVEL PROBES
HOLDING TANK
PUMP TO APPLICATION

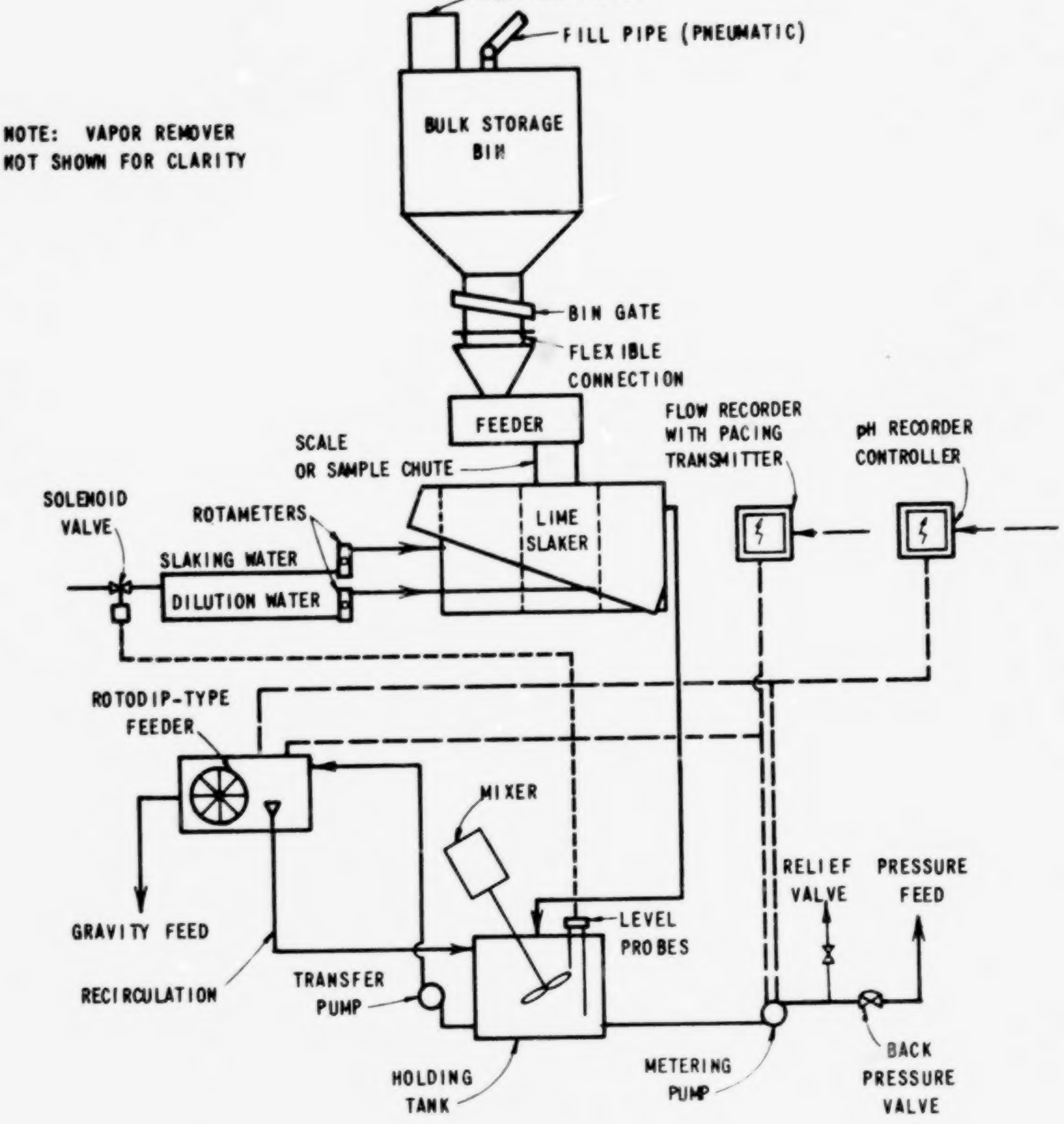
TYPICAL DRY FEED SYSTEM


OVERHEAD STORAGE TANK
RELIEF VALVE
BACK PRESSURE VALVE
CONTROL VALVE
FLOAT VALVE
ROTAMETER
METERING PUMP
ROTODIP-TYPE FEEDER
GRAVITY FEED
GRAVITY FEED
GRAVITY FEED

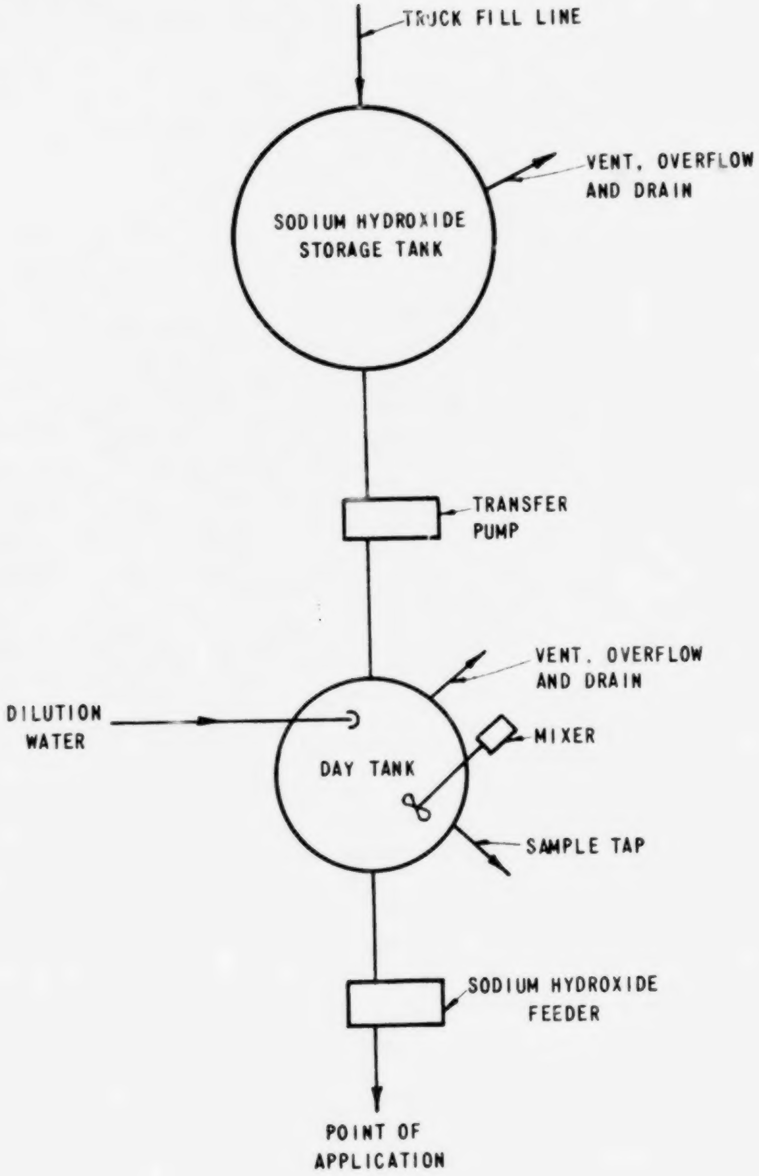
ALTERNATIVE LIQUID FEED SYSTEMS
FOR OVERHEAD STORAGE


PRESSURE FEED
CONTROL VALVE
ROTODIP-TYPE FEEDER
ROTAMETER
RELIEF VALVE
BACK PRESSURE VALVE
CENTRIFUGAL FEED PUMP
METERING PUMP
PRESSURE FEED
RECIRCULATION
GRAVITY FEED
GROUND STORAGE TANK
TRANSFER PUMP

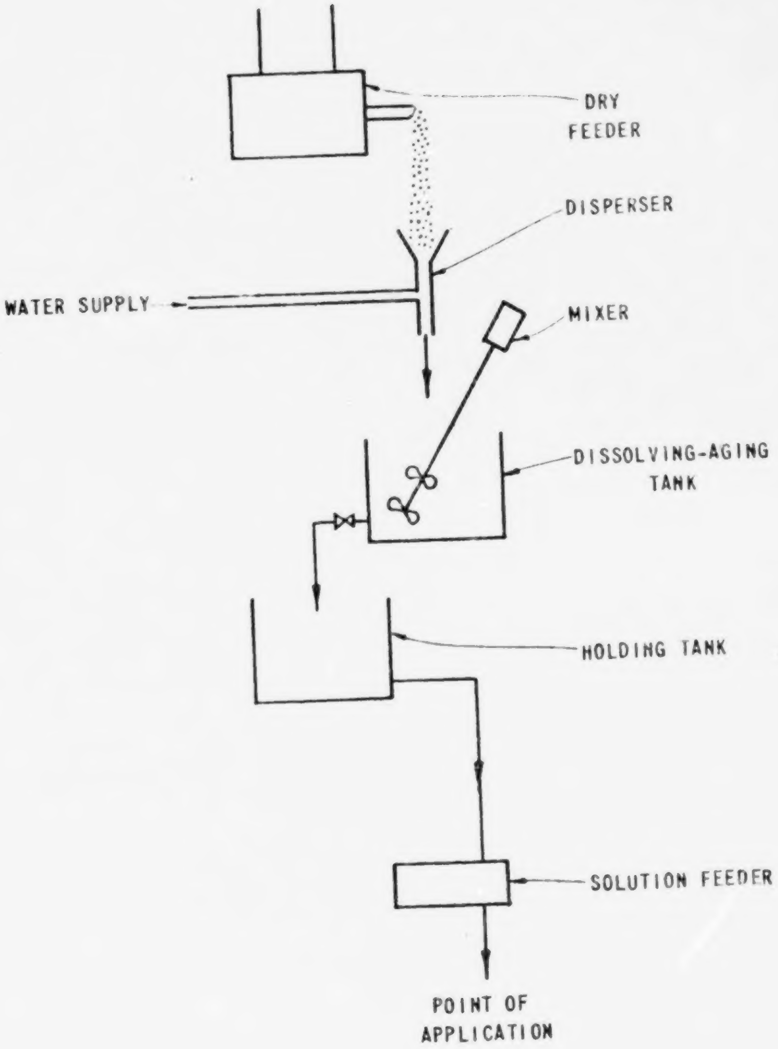
ALTERNATIVE LIQUID FEED SYSTEMS
FOR GROUND STORAGE


DUST COLLECTOR
FILL PIPE (PNEUMATIC)
NOTE: VAPOR REMOVER NOT SHOWN FOR CLARITY
BULK STORAGE BIN
BIN GATE
FLEXIBLE CONNECTION
FEEDER
SCALE OR SAMPLE CHUTE
FLOW RECORDER WITH PACING TRANSMITTER
pH RECORDER CONTROLLER
SOLENOID VALVE
ROTAMETERS
SLAKING WATER
DILUTION WATER
LIME SLAKER
ROTODIP-TYPE FEEDER
MIXER
GRAVITY FEED
RECIRCULATION
TRANSFER PUMP
LEVEL PROBES
RELIEF VALVE
PRESSURE FEED
HOLDING TANK
METERING PUMP
BACK PRESSURE VALVE

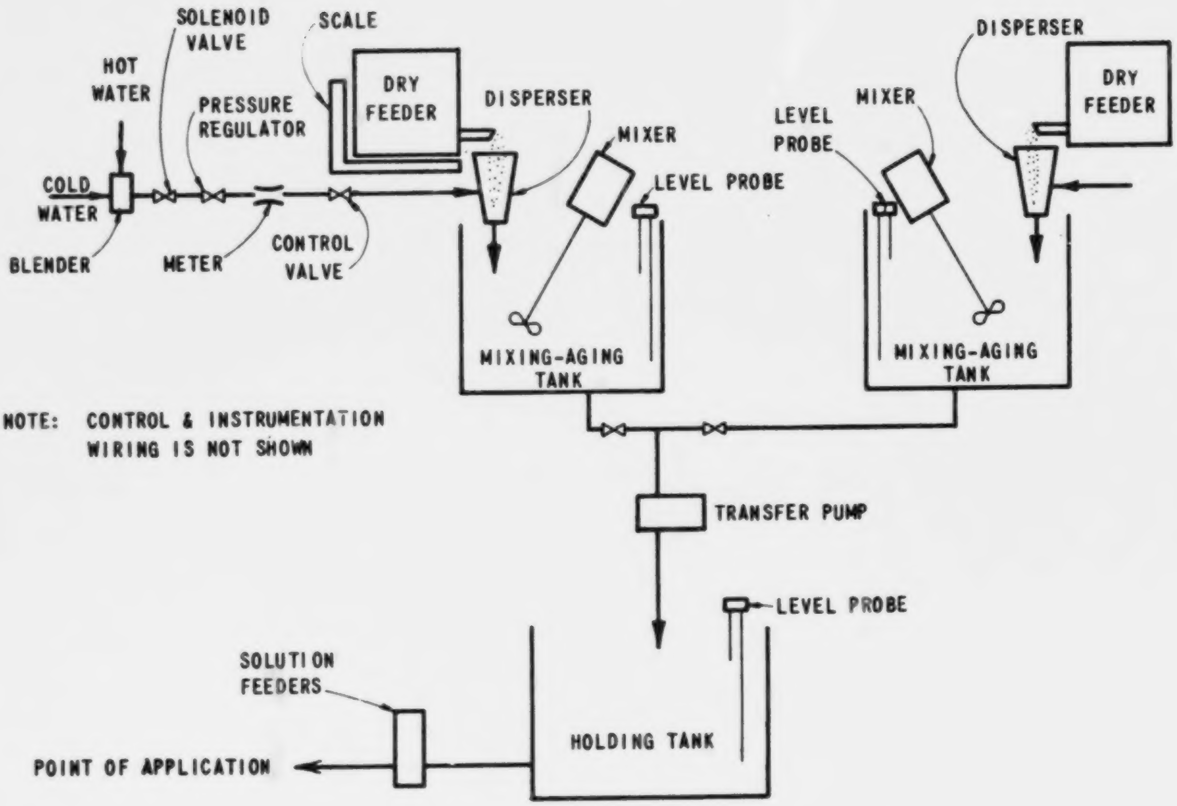
TYPICAL LIME FEED SYSTEM


TRUCK FILL LINE
VENT, OVERFLOW AND DRAIN
SODIUM HYDROXIDE STORAGE TANK
TRANSFER PUMP
VENT, OVERFLOW AND DRAIN
DILUTION WATER
MIXER
DAY TANK
SAMPLE TAP
SODIUM HYDROXIDE FEEDER
POINT OF APPLICATION

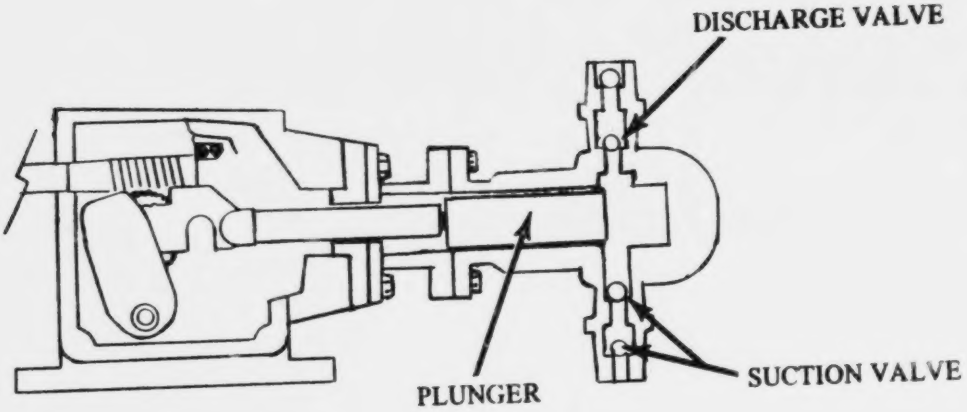
TYPICAL CAUSTIC SODA FEED SYSTEM


DRY FEEDER
DISPERSER
WATER SUPPLY
MIXER
DISSOLVING-AGING TANK
HOLDING TANK
SOLUTION FEEDER
POINT OF APPLICATION

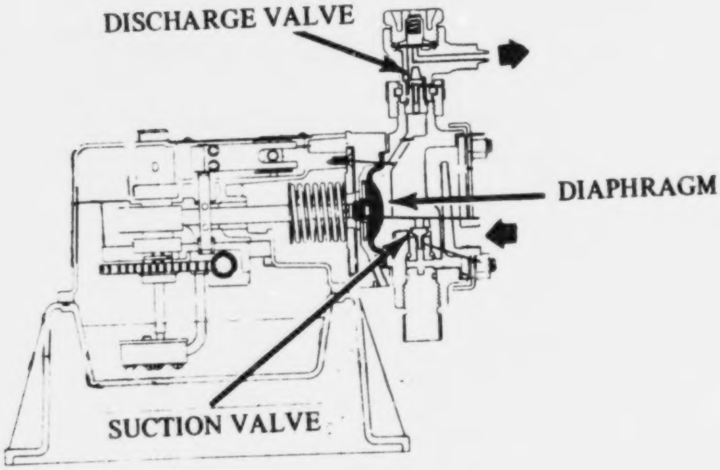
TYPICAL SCHEMATIC OF A DRY POLYMER FEED SYSTEM


HOT WATER
SOLENOID VALVE
SCALE
DRY FEEDER
DISPERSER
PRESSURE REGULATOR
MIXER
LEVEL PROBE
COLD WATER
BLENDER
METER
CONTROL VALVE
MIXING-AGING TANK
DISPERSER
DRY FEEDER
MIXER
LEVEL PROBE
MIXING-AGING TANK
NOTE: CONTROL & INSTRUMENTATION WIRING IS NOT SHOWN
TRANSFER PUMP
LEVEL PROBE
SOLUTION FEEDERS
HOLDING TANK
POINT OF APPLICATION

TYPICAL AUTOMATIC DRY POLYMER FEED SYSTEM


DISCHARGE VALVE
SUCTION VALVE
PLUNGER

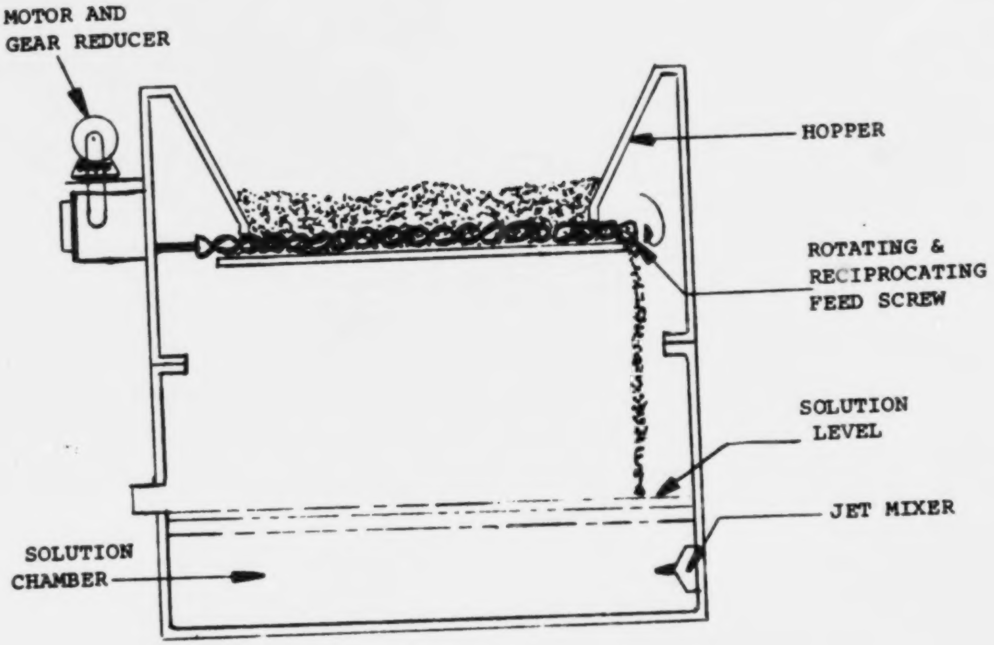
PLUNGER PUMP (Courtesy of Wallace & Tiernan)

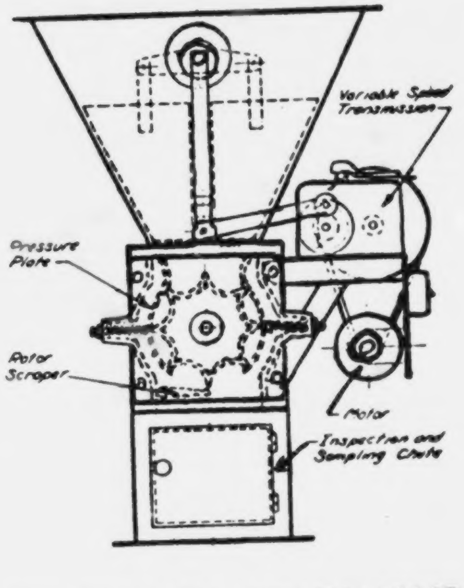

DISCHARGE VALVE
DIAPHRAGM
SUCTION VALVE

DIAPHRAGM PUMP (Courtesy of Wallace & Tiernan)

POSITIVE DISPLACEMENT PUMPS

SCREW FEEDER


MOTOR AND
GEAR REDUCER
HOPPER
ROTATING &
RECIPROCATING
FEED SCREW
SOLUTION
LEVEL
JET MIXER
SOLUTION
CHAMBER


Variable Speed
Transmission
Pressure
Plate
Rotor
Scraper
Motor
Inspection and
Sampling Chute

POSITIVE DISPLACEMENT SOLID
FEEDER—ROTARY (15)

TYPES OF CHEMICAL FEEDERS

Type of Feeder	Use	Limitations General	Capacity cu ft/hr	Range
Dry feeder:				
Volumetric:				
Oscillating plate	Any material, granules or powder.		0.01 to 35	40 to 1
Oscillating throat (universal)	Any material, any particle size.		0.02 to 100	40 to 1
Rotating disc	Most materials including NaF, granules or powder.	Use disc unloader for arching.	0.01 to 1.0	20 to 1
Rotating cylinder (star)	Any material, granules or powder.		8 to 2,000 or 7.2 to 300	10 to 1 or 100 to 1
Screw	Dry, free flowing material, powder or granular.		0.05 to 18	20 to 1
Ribbon	Dry, free flowing material, powder, granular, or lumps.		0.002 to 0.16	10 to 1
Belt	Dry, free flowing material up to 1½-inch size, powder or granular.		0.1 to 3,000	10 to 1 or 100 to 1
Gravimetric:				
Continuous–belt and scale	Dry, free flowing, granular material, or floodable material.	Use hopper agitator to maintain constant density	0.02 to 2	100 to 1
Loss in weight	Most materials, powder, granular or lumps.		0.02 to 80	100 to 1
Solution feeder:				
Nonpositive displacement:				
Decanter (lowering pipe)	Most solutions or light slurries		0.01 to 10	100 to 1
Orifice	Most solutions	No slurries	0.16 to 5	10 to 1
Rotameter (calibrated valve)	Clear solutions	No slurries	0.005 to 0.16 or 0.01 to 20	10 to 1
Loss in weight (tank with control valve).	Most solutions	No slurries	0.002 to 0.20	30 to 1
Positive displacement:				
Rotating dipper	Most solutions or slurries		0.1 to 30	100 to 1
Proportioning pump:				
Diaphragm	Most solutions. Special unit for 5% slurries.[1]		0.004 to 0.15	100 to 1
Piston	Most solutions, light slurries.		0.01 to 170	20 to 1
Gas feeders:				
Solution feed	Chlorine		8000 lb/day max	20 to 1
	Ammonia		2000 lb/day max	20 to 1
	Sulfur dioxide		7600 lb/day max	20 to 1
	Carbon dioxide		6000 lb/day max	20 to 1
Direct feed	Chlorine		300 lb/day max	10 to 1
	Ammonia		120 lb/day max	7 to 1
	Carbon dioxide		10,000 lb/day max	20 to 1

[1] Use special heads and valves for slurries.

EXAMPLE 2 – INNOVATIVE PLANT PERSONNEL AND ALUM MAKE SUCCESSFUL PHOSPHORUS REMOVAL TEAM AT GRANDVILLE, MICHIGAN*

INTRODUCTION

Grandville, Michigan was a community that relied on septic tanks until 1964. In 1964 a 1.6 MGD activated sludge plant was put into operation. It was expanded to 3.2 MGD in 1969 to incorporate Hudsonville, Georgetown, and Ottawa Townships. It was during this expansion that phosphorus removal equipment was added. The plant has an average flow of approximately 2.4 MGD.

PHOSPHORUS REMOVAL EQUIPMENT

The City installed two 5,000 gallon fiberglass storage tanks, two 500 gallon fiberglass day storage tanks and two metering pumps. From the pump the coagulant is carried to the points of application in PVC lines suspended in conduits. By installing the feed lines in conduits, access for maintenance and ground warmth to prevent coagulant freezing are insured. From the PVC lines in the conduits, flexible rubber hosing carries the coagulant to the most effective point of application. The rubber hosing permits easy moving of the feed point to maximize particular coagulant efficiencies, and the ability to easily check coagulant feed into graduated cylinders (cc's per minute).

CHEMICAL TREATMENT

A twenty-four hour profile of influent phosphorus values was made. Based on this profile, two chemical feed rates were established. From 11:00 p.m. to 8:00 a.m. the City found they could save money and chemicals by cutting the feed rate by 1/3 and still maintain the same level of phosphorus removal.

Chemical treatment began in December 1973 with the use of Ferric Chloride at a dose rate of 60 mg/l $FeCl_3$. Phosphorus removals ranging from 33.5% to 80% were experienced. On June 21, 1974, the City began the use of Liquid Aluminum Sulfate (Alum). An initial test dosage of 150 mg/l was found to be too high and was reduced to a range of 69-80 mg/l. From June 24, 1974 to the present, the City has met the 80% phosphorus removal requirement consistently with an average 82.8% removal (see Chart 1). Suspended solids removal increased from 82.3% to 91.4% average removal when they changed from ferric chloride to alum (see chart 2). The City splits the feed of alum in the primaries and secondaries during the summer to reduce the loading on the secondary stage. During the winter alum is added to the end of the activated sludge unit.

* Taken from Wastewater News, Allied Chemical Company

INTERESTING NOTE

Mr. Glenn Folk, Superintendent of the facility, made note of the benefits of residual aluminum values in the recycle of his activated sludge. This is based on the observation that, during start-ups, high initial doses do not remove phosphorus as well as when the recycled sludge has built up an aluminum value. In fact, he noted that during a maintenance shutdown, the recycled sludge continued to remove phosphorus at high efficiencies for a period of time when the alum feed was discontinued. This is consistent with our observation that aluminum values in the recycle of activated sludge usually allow smaller alum dosages.

CHLORINE SAVINGS

Before phosphorus removal began, the City used approximately 27 pounds of chlorine per million gallons to maintain a chlorine residual of 0.5 mg/l. Since the plant began the use of alum, they have been able to maintain the same 0.5 mg/l chlorine residual by using 19.6 pounds of chlorine per million gallons, for a chlorine savings of about 28%.

SLUDGE

The primary sludge is treated by anaerobic digestion and the waste activated sludge is treated by aerobic digestion. Grandville has not experienced pH depression problems in either operation during alum usage, but two things were discovered. When alum is dosed in the primaries, the primary sludge became mohomogeous and easier to handle. When dosed in the secondaries, the sludge going to the digestors increased in percent solids from 1% to 1.25% and sludge from the digestors increased to 5% solids, compared to 3% before alum use.

MAINTENANCE

Grandville's good preventative maintenance program helps to keep the plant operating well. This program includes the regular flushing of lines and storage tanks to remove any possible accumulation of solids. Previous experience with solids accumulation led to this practice. Others may find this practice of value.

The innovations at Grandville's plant by Mr. Glenn Folk and his staff have resulted in a high degree of performance. We appreciate the opportunity to highlight his efforts and to publicize the excellent results.

Chart #1
Total Phosphorus and Percent Removal
Grandville, Michigan Plant

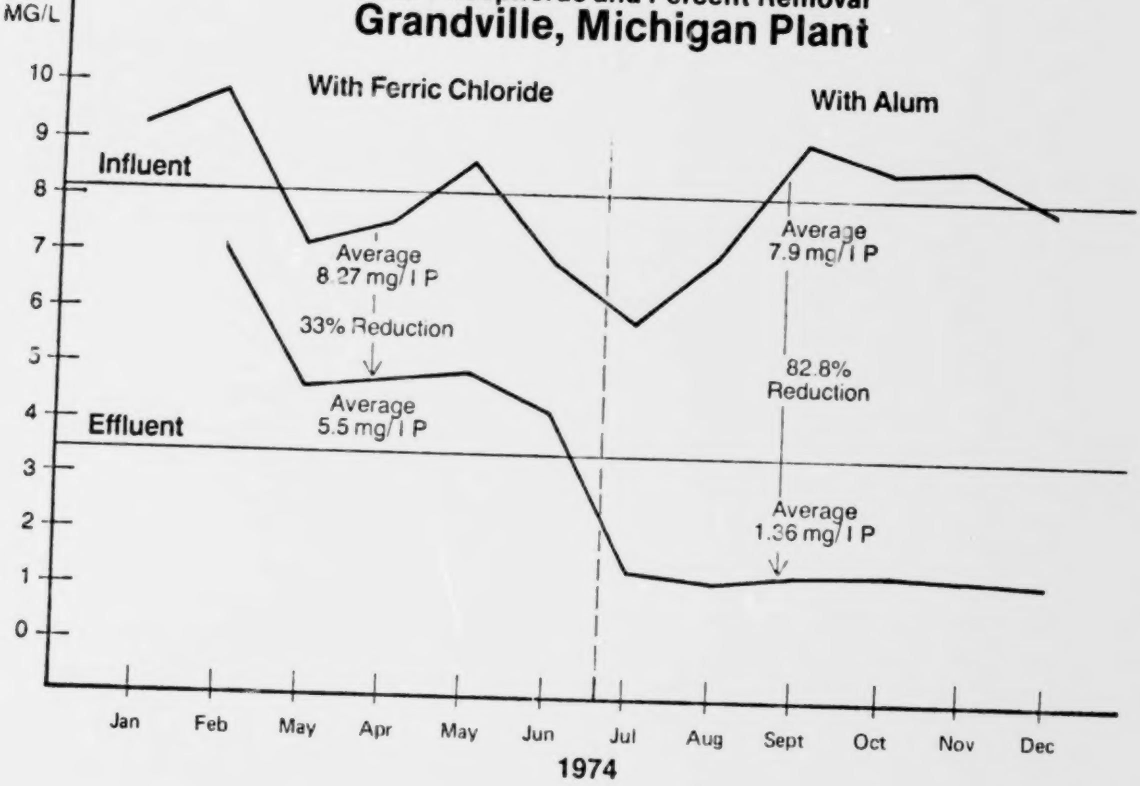
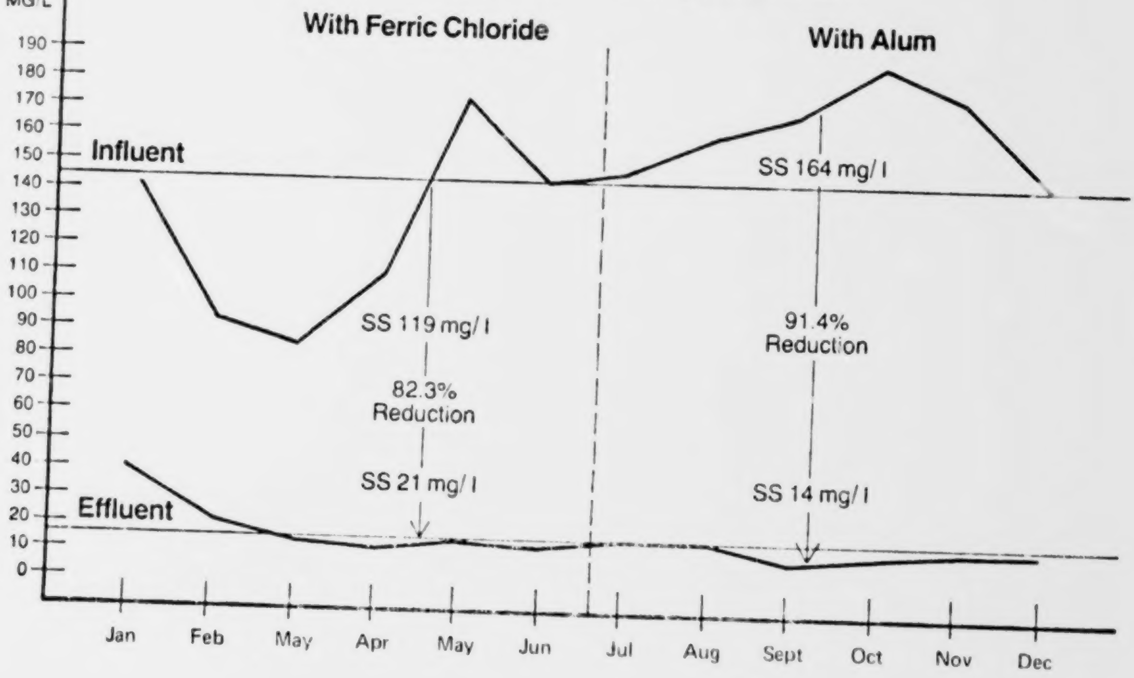


Chart #2
Suspended Solids and Percent Removal
Grandville, Michigan Plant



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LESSON – MANAGEMENT BEHAVIOR

Instructor Overview of Lesson

Entry Level Behavior: Students will have had University training in Sanitary Engineering, waste treatment and/or related sciences or equivalent in experience and training. Some field experience in inspecting treatment facilities, but none in operating waster treatment facilities. It is likely that few students will have any management experience.

As a prerequisite to this course, it is recommended that the student will be able to –

1. Identify treatment plant process units.
2. Describe treatment plant process units and equipment in technical terms.
3. Identify and explain the purpose of components of treatment plant process units, how they work and why they are important to the overall process.
4. Describe the normal operating procedures for treatment plant process unit components.
5. Identify when treatment plant process units are not operating properly.

Instructor Objectives: The principal instructor objectives for this lesson are:

1. To relate management to treatment plant operations and performance.
2. To provide guidance on when and how to troubleshoot management problems at treatment plants.
3. To present the Process of Troubleshooting as an approach to dealing with management problems.
4. To identify problems in Management Systems.
5. To provide guidance to assist plant operators in developing management systems.

References: Note list of references included with Student Notebook materials.

Total Length of Lesson: 2 Subdivisions, 2 Hours.

LESSON OVERVIEW

Subdivision Title & Time	Major Student Objectives	Key Points & Content	Approach	Materials
1. Management Behavior and Treatment Plant Operations	1. Recognize management as applies to treatment plants	1. Treatment plants, like anything else, need management	1. Approach is to be informal, stressing conversation rather than lecture	1. To preserve the informal nature of this subdivision no prepared training materials are used other than the instructor's lesson outline
	2. Understand how management is related to people and to plant operations	2. Management determines plant operation and performance	2. Considerable student input is asked for, some of which is to be recorded at the chalkboard using a student recorder	
50 Minutes	3. Describe the indirect role of troubleshooters in dealing with management problems	3. Judgment is needed to determine the troubleshooter's role in dealing with management problems		
	4. Define and list several management skills and systems	4. Management systems serve as management tools in treatment plants		
2. Troubleshooting Management Systems	1. Approach identifying management problems in treatment plants	1. Any facet of plant operation can be hurt by poor management	1. Instructor uses lesson outline, word slides and key.	1. Chart, Process of Troubleshooting
	2. Assist treatment plant operators in developing management systems	2. Observation, and talking to plant personnel is a key to identifying mangement problems	2. Student discussion is to be stimulated	2. Word slides — 11 slide series, and key
70 Minutes	3. Evaluate and develop maintenance management systems	3. Management systems can be developed, with assistance from available materials	3. Students work in group to solve management problem Problem results to be discussed by class	3. Problem description and answer sheets, Student Notebook pages MB-1 to MB-3
	4. Recognize the impact of external factors in managing a treatment facility	4. Troubleshooters must recognize problems that an operator is faced with	4. Section III relies heavily on material provided in Student Notebook	4. Materials on developing maintenance management systems, Student Notebook pages MB-4 to MB-21

LESSON – MANAGEMENT BEHAVIOR

Presentation Options for Course Director

Management Behavior is an important subject area covered in this course, and is important to a troubleshooter's efforts in providing technical assistance to plant operators. It is also a subject in which technically trained field personnel are likely to have little experience, and perhaps even little appreciation. However, experience with this course and discussions with many persons who are involved in troubleshooting problems at treatment plants, emphasize the belief that Management Behavior is an important area of plant operation to look at.

This lesson can be expanded or shortened depending on the needs of the student groups and the Course Director. In relation to a total course time of 28 to 40 hours, the existing time of presentation of 2 hours is appropriate. If the lesson needs to be significantly shortened for any reason, it can be shortened to about 1 hour, by including all of Subdivision 1 and parts of Subdivision 2. There are also opportunities for expanding this lesson if it serves the needs of the Course Director and the students taking the course.

Some of the presentation options are as follows:

Subdivision 1 – Management Behavior and Treatment Plant Operations:

The existing 50 minute lesson is an important introduction to the topic of Management Behavior. In addition, it employs an informal style which is useful in this course, particularly as a break from some of the more highly structured lesson materials that are presented in other lessons. If Management is to be treated as a serious topic in this course, then this subdivision should remain intact. One option for the Course Director would be to invite a person or persons who are involved in plant management to participate in the lesson. Such persons could be used as resources during the lesson, to be involved with the students and the instructor in an informal discussion kind of format. This could prove to be very interesting and useful to the lesson.

Subdivision 2 – Troubleshooting Management Systems:

This subdivision contains some general material on Troubleshooting Management Systems, in Sections I and II, and then some very specific material on developing maintenance management systems used as an example on developing management systems overall. The general material in Sections I and II is important to the lesson in that it stresses the approach to troubleshooting that can be used for dealing with management problems. The specific material used in Section III can be replaced by the instructor with material available on developing other types of management systems. Maintenance Management Systems has been selected for this lesson because of the general interest in this area, and the availability of materials through an EPA manual. However, the same discussions could center around safety, record keeping, personnel, training, or any other management system commonly employed in a treatment plant.

This subdivision can easily be expanded by including information about additional management systems. This should be at the discretion of the Course Director.

Other Subjects:

In some of the presentations of this course that have been made during its development, the Management Behavior lesson has provided a good opportunity for extended class discusssions on related materials. Some of these topics may be of interest to the Course Director during any presentation of the course. Some of the topics that may be discussed include:

1. The appropriateness of troubleshooting management problems in treatment plants, (an expanded discussion of the topic which is covered under Subdivision 1).
2. Problems in dealing with external management situations, (an expansion of the topic which is covered briefly under Subdivision 2).
3. The role of consulting engineers in troubleshooting and operating treatment plants. This topic has frequently come up in areas where the course has been presented, and may be of interest to the Course Director. If so, the presence of one or two engineering consultants during such a discussion could be of interest to the students. The developers of this course have found that there is a great deal of misunderstanding regarding the role of consulting engineers, and state and federal people tend to blame them for many of the problems which they have found in the field in the operations of treatment plants. This is an area which needs clarification and communication, and this lesson provides an opportunity for discussions of those issues.

Finally, other topics of interest to the Course Director may be included under the Management Behavior lesson. It affords a good opportunity to take a break from more formal course material and to open up considerable student discussion.

MANAGEMENT BEHAVIOR

Lesson Plan – Subdivision 1 **Time: 50 Minutes**

Title: Management Behavior and Treatment Plant Operations

Instructor Objectives: To introduce the subject of management, and relate it to treatment plant operations and performance. To guide the students toward determining when and how they will be able to troubleshoot management problems at treatment plants.

Student Objectives: As a result of this lesson subdivision, students will be able to do the following:

1. Identify a wastewater treatment plant as an enterprise similar to many other types of establishments.
2. Recognize the application of management to a wastewater treatment plant.
3. Understand the relationship of management to people and to plant operations.
4. Assess their own level of competence as a "management consultant" and recognize that they, like the other students, are not qualified to be management consultants.
5. Describe the indirect role that troubleshooters can play in assisting operators with management problems.
6. Determine when and how it is appropriate to get involved in troubleshooting management problems.
7. Define managemnt "systems" and management "skills".
8. List several management "systems" and "skills" appropriate to treatment plant management

Training Materials:

To preserve the informal nature of this subdivision, no prepared training materials are used other than the instructor's lesson outline.

Classroom Set-up:

A normal classroom set-up will be required

Students should be seated with their student groups

Chalkboard or easel

Pointer

Subdivision Schedule:

Within the 50 minute time period, the following schedule should be observed in presenting the lesson plan outline.

TIME	SUBJECT
0-15 Minutes	Management, and why it is important
15-35 Minutes	Relating troubleshooting to management
35-50 Minutes	Management systems

Subdivision Approach:

This subdivision is intended to be *informal*, with the principal means of communication to be conversation rather than lecture. Therefore, no slides or charts are used.

The instructor is to use the chalkboard at two points in the discussion.

In Section II, the instructor calls for student responses to questions, and then challenges the class on their management experience in order to make the point that they are not expected to be management experts.

Section III calls for considerable student input which, if necessary, must be stimulated or prodded by the instructor.

Please note that there are several guides on how to present this material along with the lesson outline.

LESSON OUTLINE

I. Management, and Why It Is Important (15 Minutes)

- A. Introcution to Lesson – Objectives of the Lesson on Management Behavior as applied to troubleshooting treatment plants:
  1. Management behavior is an important factor in how well a treatment plant is operated.
  2. Management is the system by which the capabilities of people and plant facilities are combined to get the most out of the waste treatment systems of the plant.
  3. Management requires management skills – which many persons are very weak on.
  4. Management can be facilitated with "management systems," i.e., systematic programs for accomplishing the various management responsibilities within a treatment plant.
  5. Management systems can be evaluated and improved by using the Process of Troubleshooting, just as physical systems can be.

- B. Management of Wastewater Treatment Plants
  1. We think of "management" as something applied to a business or industry. In what ways does it apply to a treatment plant? Use the following logic to develop the argument that treatment plants need management.
  2. Characterizing a Waste Treatment Plant. A treatment plant may be thought of as being:
     - a. A *manufacturing enterprise* – producing clean water, and an unwanted by-product, sludge.
     - b. A *materials handling* facility – handling tons of materials per day – solids, liquids, and gases.
     - c. A *controlled biological environment* – a place where we let nature "do its thing."
     - d. A *public service* – providing clean water for public rivers, streams, lakes and oceans.

KEY POINTS & INSTRUCTOR GUIDE

Guide: Use this section to introduce the lesson, and to relate management to overall plant operations.

LESSON OUTLINE

3. Thus, in a general sense, a treatment plant is no different from other establishments, in that:
    a. There is a job to be done, a product to be produced.
    b. High product quality is sought – in fact, is legally required.
    c. There is a cost – thus cost efficiency is necessary.
4. Having to meet all of the above requirements, is there any doubt that treatment plants need good management?

C. Making a Treatment Plant Work

1. The primary function of a treatment plant is to produce an acceptable effluent, one which meets permit requirements, effluent limitations, and which prevents the degradation of water quality in the receiving body of water.
2. Treatment plants operate through various unit operations and processes, which employ:
    a. Physical forces – heat, gravity, pressure, etc.
    b. Chemical reactions
    c. Biological activity – hopefully controlled
3. Treatment plant processes require (among other things)
    a. Equipment – tankage, mechanical devices
    b. Materials – chemicals, media, oxygen
    c. Transport mechanisms – pipes, channels, shovels, trucks
    d. Control mechanisms – valves, weirs, dosage controls
    e. Analytical devices – gauges, samplers, laboratories
4. What makes treatment plant processes function?
    a. *Operations* provide for the right mix and timing of materials, equipment, etc.
    b. *Maintenance* allows operations to proceed normally

KEY POINTS & INSTRUCTOR GUIDE

Key Points: Treatment plants need management just like anything else.

LESSON OUTLINE

c. Operation of a plant is managed: it is
   1. scheduled
   2. staffed
   3. paid for
   4. equipped

5. People make operation possible – and the "operating program" which assures that people perform as planned is *management*.

   Good management is the means by which people (plant personnel) do the right things at the right time, to get the most out of the treatment facility.

6. Illustrate, by drawing the following diagram on the chalkboard.

Management → People → Operation → Processes → Wastewater Treatment → Clean Water

   The diagram should be explained in these simple terms:

   a. *Management*, determines what *people* do,
   b. To *operate* treatment *processes*,
   c. Which comprise a *wastewater treatment* plant,
   d. Which produces clean water.

7. Allow for discussion and questions at this point.

II. Relating Troubleshooting to Management In a Treatment Plant (20 Minutes)

   A. Determine what the class knows about management.

   (The point of the questions is to show that the students don't know too much about management!)

   Ask the class (by a show of hands) to answer the following questions:

   1. How many students have operated a treatment plant?
   2. How many students have managed, or have been a chief operator or superintendent of a treatment plant?

KEY POINTS & INSTRUCTOR GUIDE

Key Point: This diagram should be used to illustrate how management determines treatment plant operation and performance.

Guide: In this segment, the instructor should relate the students' own experiences to management. Most students in the course will have little or no management experience. Allow for class discussion.

Guide: The instructor should approach this segment as he would a *conversation* with the students. He should be informal, and should not attempt to lecture or instruct!

LESSON OUTLINE

KEY POINT & INSTRUCTOR GUIDE

3. How many students have people (staff) working for them now?
4. How many students have a budget to administer?
    a. Those that do – how many $?
5. How many students have dealt with labor problems?
6. How many students have run an organization or company which has been regulated by a state or federal agency?

B. Based on the response to the question in Section A, CHALLENGE the students by asking:

1. What makes them think they are qualified to be management consultants?
    ANSWER: They're not – BUT – they're not expected to be management consultants.
2. How can they, with their backgrounds, possibly solve management problems?
    ANSWER: They can't – BUT – they can recognize when management problems affect plant operations, and in some cases, they can work WITH operators and superintendants to help them solve their own problems.

Guide: The point of this section is to show that the students are not *qualified* to be management consultants – but that they are not expected to be. By working *with* operators, and by knowing about *management systems*, they can still be of help as troubleshooters.

3. Should field personnel, i.e., troubleshooters, get involved and attempt to work on the solution of management problems?
    ANSWER: Good question, let'd discuss it!

Guide: This question deals directly to the next section. Allow for full class discussion of this topic.

C. The Role of a Troubleshooter in Dealing with Management Problems

Note: This question often is of great interest, and becomes the subject of considerable discussion. Discussion should be allowed to continue as long as it is fruitful and relevant to the overall lesson.

Also, it should be noted that different states and agencies may have different policies on this question – of how deeply a troubleshooter should get involved in management problems.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
1. Upon visiting a treatment plant, troubleshooters should be able to recognize when plant operational problems *may* be caused by management difficulties (hopefully this lesson will assist them in recognizing management problems).	
2. With a knowledge of management systems (to be covered in this lesson following this section) troubleshooters, in many cases, should be able to provide constructive assistance.	
3. This leaves the question of whether they should attempt to provide assistance!	
a. This may depend in part on the reason for visiting the plant in the first place, and the circumstances by which a troubleshooter may be asked to help.	Guide: Note that this point has already been discussed; in part, in the lesson Elements of Troubleshooting.
b. It depends upon the troubleshooter's relationship with the plant operator and superintendent, and past relationships between the agency and the municipality.	
c. If there is doubt in the troubleshooter's mind as to whether he should involve himself – he should consult his supervisor before proceeding.	
d. Sometimes problems of a management nature should be "bounced up" to people in the agency who have been on the job longer, and who are better known to the municipal people. In some cases, they can be better handled on the "political" level than on the technical level.	Key Point: This question boils down to the point that the troubleshooter's judgement must be used in determining if and how he should get involved in management problems.
e. When getting involved in a management problem, a troubleshooter must remember that he cannot solve it – but he can work with others to help them solve it.	
4. Call for general class comment and discussion on this issue.	

LESSON OUTLINE

III. Management Systems (15 Minutes)

A. Management — in a treatment plant or anywhere else, is getting things done through people.

B. Good management means having *control* over the physical facilities and processes in a plant, control that is obtained through the operation of those facilities by people. (Even in cases where a process is automatically operated, it takes people to program and monitor those operations).

C. Management activities are based on a collection of personal and professional skills, skills which many people have little of, but which some people can learn.

1. Some people have ample management talent
2. Others have little or more — including many engineers and scientists.

D. Management skills can be supplemented and strengthened by using management systems.

Management systems:

1. Are organized programs designed to help people perform and meet their management responsibilities.
2. Put management on a very systematic and routine basis, and thus simplify it considerably.
3. Can help the unskilled manager to do his job successfully.

E. Identifying Management Systems.

1. Recorder should set up two columns on the chalkboard —

   Management Systems   Management Skills

2. Instructor categorize each input as a "skill" or a "system";
3. Recorder should write down each input

KEY POINTS & INSTRUCTOR GUIDE

Guide: The point of this section is to show that there exists, various management *systems*, which when used to operate a treatment plant, facilitate good management.

Guide: Select one student to be the class recorder, using the chalkboard. Have the class contribute their ideas as to what are management skills and systems. The instructor should categorize each input as a "skill" or a "system." Note that some can be both.

LESSON OUTLINE

4. Some likely responses will be:
   a. *Management Systems*
      - Maintenance
      - Safety
      - Staffing
      - Training
      - Personnel
      - Contingencies
      - Reporting
      - Record Keeping
      - Bookkeeping
      - Planning
      - Communication
      - Organization

   b. *Management Skills*
      - Supervision
      - Organization
      - Interviewing
      - Contingencies
      - Delegation
      - Writing
      - Communication
      - Decision Making

5. Characteristics of Management Systems
   a. Management systems are *developed* – thus they serve as management tools – even for persons with poor management skills.
   b. There are aides, and guidelines and manuals for the development of management systems – one need not be an expert.
   c. Management systems make it possible to overcome deficiencies in management skills.
   d. Management systems make it possible to develop and improve management skills in individuals.
   e. Management systems give the troubleshooter a target for troubleshooting management problems in a treatment plant.

F. Troubleshooting Management Systems

Troubleshooters *can* deal with management systems, even if they have few management skills themselves.

1. Troubleshooters can note the presence or absence of a necessary management system in a treatment plant.

KEY POINTS & INSTRUCTOR GUIDE

Guide: With these lists on the chalkboard, make the following points.

Key Point: By observing and understanding management systems, a troubleshooter can assist an operator in dealing with his management problems.

LESSON OUTLINE

2. Troubleshooters can recommend the institution of a management system.
3. Troubleshooters can assist operators and superintendants in employing and developing management systems.
4. EPA and others have developed guides – and programs for management systems – i.e. staffing, maintenance, training safety. Troubleshooters can utilize these materials.
5. Troubleshooters *cannot* teach an operator how to develop management skills.
6. Troubleshooters can only solve management problems indirectly – through the operator and the use of management systems.

G. Questions and Discussion

KEY POINTS & INSTRUCTOR GUIDE

Guide: Allow for discussion before going on to the next subdivision.

MANAGEMENT BEHAVIOR

Lesson Plan - Subdivision 2 **Time: 70 Minutes**

Title: Troubleshooting Management Systems

Instructor Objectives: To present an approach to dealing with management problems in a wastewater treatment plant by using the Process of Troubleshooting. To guide the students in identifying problems in management systems, and in assisting plant operators to develop management systems where none exist.

Student Objectives: As a result of this lesson subdivision, students will be able to do the following:

1. Approach identifying management problems that may cause operational problems in wastewater treatment plants.
2. Make observations and recognize indicators of management problems in treatment plants.
3. Apply judgment in choosing between alternative corrections for solving management problems.
4. Assist treatment plant operators in developing management systems.
5. Identify the components of a maintenance management system in a wastewater treatment plant.
6. Combine the components of a maintenance management system into a total system.
7. Evaluate maintenance management systems in wastewater treatment plants.
8. Recognize the impact of external factors in the management of a wastewater treatment facility.

Training Materials:

Chart, Process of Troubleshooting

Slide series of 11 word slides, and slide key

Problem description – page MB-1, and answer sheets No 1 and No 2, Student Notebook pages MB-2 and MB-3

Student Notebook pages MB-4 thru MB-21, on maintenance management systems, reproduced from EPA manual, "Maintenance Management Systems for Municipal Treatment Facilities."

Classroom Set-up:

A normal classroom set-up will be required

Students should be seated with their student groups

35 mm carousel slide projector with remote controls

Large screen (8 ft x 10 ft)

Chalkboard or easel

Pointer

Subdivision Schedule:

Within the 70 minute time period, the following schedule should be observed in presenting the lesson plan outline.

TIME	SUBJECT
0 – 10 Minutes	Identifying Management Problems
10 – 40 Minutes	Management Evaluation Example
40 – 60 Minutes	Developing Management Systems
60 – 65 Minutes	Dealing with External Management Problems
65 – 70 Minutes	Summary and Questions

Subdivision Approach:

The instructor is to rely upon the lesson outline, and at some points in the lesson upon the word slides and key. Student discussion is to be stimulated.

Section II, Management Evaluation Example, students work in their groups on a problem which is partially presented on Notebook page MB-1, and partially presented orally by the instructor. Answer sheets are provided in the Student Notebook. Analysis of the problem is to be discussed within the class following group participation, and the class is to vote on the actions which they prefer to recommend.

Section III, Developing Management Systems, relies heavily on material provided in the Student Notebook.

LESSON OUTLINE

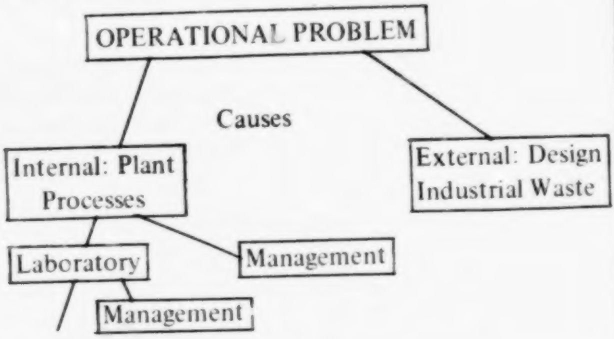
I. Identifying Management Problems (10 Minutes)

A. Management problems are identified through measures of plant performance – just as other plant problems are identified.

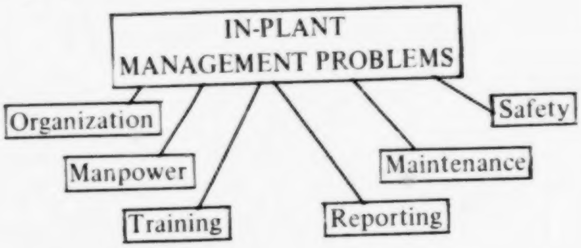
1. Is plant effluent meeting standards?
2. Are processes functioning properly?
3. Is the operator getting the most from his plant?

B. Often – the troubleshooter cannot determine immediately that a problem is due to a management deficiency rather than a technical deficiency. However, he should always consider management problems to be among the alternatives he has to choose from in determining the cause of operational problems.

C. Sometimes a deficiency in plant operations is several steps removed from a management problem that is the cause.


OPERATIONAL PROBLEM
Causes
Internal: Plant Processes
External: Design Industrial Waste
Laboratory
Management
Management

D. Management Problems can occur in any of several management systems, and have a serious impact on plant operations.


IN-PLANT MANAGEMENT PROBLEMS
Organization
Manpower
Training
Reporting
Maintenance
Safety

KEY POINTS & INSTRUCTOR GUIDE

Refer students to chart, Process of Troubleshooting. Line 2 – Formulating Alternative Solutions.

Guide: Illustrate with slide MB-1.

SLIDE MB-1 (word)

Key Point: Any facet of plant operations can be hurt by poor management.

SLIDE MB-2 (word)

LESSON OUTLINE

E. Key step in the Process of Troubleshooting as applied to Management Problems. Refer to Chart – Process of Troubleshooting

1. Line 1 – Analyze and Learn
2. Step C – Visit Plant, meet and listen, observe, review

"PROCESS OF TROUBLESHOOTING APPLIED TO MANAGEMENT"

Key Step: Analyze and learn
Visit Plant
Meet and listen
Observe
Review

F. Observation to make while Troubleshooting

1. "OBSERVATIONS TO IDENTIFY MANAGEMENT PROBLEMS"

- Busy people, little work done
- Disabled equipment
- No safety rails or guards
- Poorly kept grounds
- Sampling techniques
- Any visible sign of management laxity

2. "INDICATORS OF MANAGEMENT PROBLEMS"

- Long record of process accidents
- Obvious "dry labbing"
- No apparent chain of command
- Lack of maintenance records
- Incorrect data in reports
- Poorly trained staff

G. Troubleshooting management problems.

1. Once problems are identified that are caused by management problems or deficiencies, the troubleshooter may proceed in several ways, depending on the nature of the problem, the situation, and his relationship with the plant operator. Among the things he can do are:

KEY POINTS & INSTRUCTOR GUIDE

Guide: Use slide MB-3 to relate the Process of Troubleshooting to management.

SLIDE MB-3 (word)

Key Point: Stress the importance of talking to plant personnel, and in observing what's happening at a treatment plant.

SLIDE MB-4 (word)

Guide: Some indicators of management problems need more thorough investigation. Illustrate with Slide MB-5.

SLIDE MB-5 (word)

LESSON OUTLINE

a. Let the operator know what the problem is, and then bow out and let the operator handle it.

b. Suggest a remedy or solution to the problem.

c. Work with the operator to help him correct the problem.

d. Provide information, such as on the development of an appropriate management system.

e. Assist the operator in designing and instituting appropriate management systems.

II. Management Evaluation Example (30 Minutes)

A. Have students read problem – then discuss among their student groups.

B. Student groups should answer questions asked on answer sheet No. 1, Student Notebook p MB-2.

C. Have student groups briefly present their answers.

D. Respond to the student group presentations of their answers, then proceed by reading the second part of the problem (students do not have this in their possession).

Instructor read aloud:

All of the above were investigated with negative results. However, the case was not dropped. The Chief Operator recommended that you check these sources more closely. Weather records for the individual periods revealed no rainstorms so it was definitely ruled out. Next, the chief operator looked again at his list and quickly determined that no new connections had occurred. Of the four remaining, three were directly connected to internal operations. Therefore, a closer examination of these would be made before checking item No. 4.

A day by day investigation of plant records revealed that the regular digester operator was off at various times and was replaced by another plant operator. This operator was given a variety of oral

KEY POINTS & INSTRUCTOR GUIDE

Guide: Students have a problem description – Page MB-1 Student Notebook.

Guide: Allow 10 minutes for Steps A & B.

Guide: Allow 5 minutes for Step C.

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

instructions which weren't completely understood and he had probably overdone all three operations, thus leading to most of the plant's problems. You and the chief operator discussed six (6) alternative actions which might be taken to clear up this problem.

These are:

Guide: The six alternative actions are to be shown by using
SLIDE MB-6 (word)

"POSSIBLE CORRECTIVE ACTIONS"

1. Terminate relief operator
2. Terminate the regular operator for not giving good instructions
3. Reprimand both of them
4. Establish and post job procedures
5. Establish training for relief operators
6. Provide a better system of supervision

E. Student groups should answer questions asked on answer sheet No. 2, Student Notebook p MB-3.

Guide: Allow 5 minutes for Step E.

F. Have student groups report back their recommendations on how to correct this problem – and then implement the corrective actions. Have the class note which actions they recommend – by a show of hands.

Guide: Allow 5 minutes for Steps F & G, or more if lively discussion continues.

G. Discuss the merits of a constructive approach (Corrective actions 4, 5, & 6) as opposed to a punitive approach (actions 1, 2, & 3).

III. Developing Management Systems (20 Minutes)

A. When called upon, a troubleshooter may be able to assist an operator in the development of needed management systems in a plant.

1. EPA and other materials are available to help in this activity. Example, cite EPA Manuals

a. "Maintenance Management Systems for Municipal Wastewater Facilities"

Guide: Much of this section is taken from material in this EPA Manual, "Maintenance . . ."

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
b. "Estimating Staffing for Municipal Wastewater Treatment Facilities."	Guide: As an example of developing management systems, this section will focus on setting up a maintenance management system.
B. Components of Maintenance Management Systems	Guide: Select one student to be a recorder at the chalkboark. Have the class suggest what different components of a maintenance management system would be, record on board.
1. "COMPONENTS OF MAINTENANCE MANAGEMENT SYSTEM" • Equipment record system • Scheduling and planning • Storeroom and inventory • Personnel and organization • Costs and budget • Correlating the components into a complete system.	Use SLIDE MB-7 (word) to list components as taken from the Table of Contents of the EPA Manual.
2. Equipment record system. An example of an equipment records system for small plants would be a single card file system, with one card used for each piece of equipment.	For the remainder of this section, reference is made to material in the Student Notebook, reprinted from EPA Manual, "Maintenance Management Systems." Have students follow lesson by using their Notebooks. Reference: Student Notebook page MB-4.
3. Maintenance scheduling and planning systems are needed so that things get done when they are supposed to.	
a. Typical daily and weekly routine maintenance schedules.	Reference: Notebook pages MB-5 and MB-6.
b. Typical Maintenance Work Order	Notebook page MB-7.
4. Storeroom and Inventory System	Notebook page MB-8.
a. Sample Inventory card	
5. Personnel and Organization	
a. Manual has listing of various job titles and responsibilities.	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
b. Typical maintenance Organization Charts	
1. Plant under 10 mgd	Notebook page MB-9.
2. Plant 10-50 mgd.	Notebook page MB-10.
6. Costs and Budget	
a. Maintenance Cost Trends – very important records to determine overall level of plant maintenance and performance.	Notebook page MB-11.
C. Putting the components together into one maintenance management system.	Notebook pages MB-12 thru MB-14.
1. Notebook pages MB-12 thru 14 contain the first 3 pages of an extensive section on developing a maintenance management system for small, medium, and large plants.	
2. In large plants, the ultimate system is a computerized maintenance program.	Notebook page MB-15.
D. Evaluating Maintenance Management Systems	Notebook pages MB-16 thru MB-21.
1. EPA provides evaluation guidelines for maintenance management systems that are very useful for troubleshooting such systems.	Guide: Briefly review guidelines with class.
E. Other Management Systems	
1. Other management systems also lend themselves to a systematic development, similar to maintenance management.	
2. Troubleshooters have a great opportunity to assist municipalities in upgrading and developing such systems.	
IV. Dealing with External Management Problems (5 Minutes)	
A. Troubleshooters should recognize that plant operators and superintendents must deal with a variety of management problems of an origin external to the plant.	Guide: This topic should be covered briefly, with as much discussion as there is interest, and as time allows.
1. The larger the municipality, the more impact external management problems are likely to have.	

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

2. Many external problems cannot be tackled by troubleshooters directly, although they may be able to provide guidance if they have experience in those areas. However, troubleshooters must be aware of, and should be understanding of the external management problems confronting treatment plant operators.

Key Point: Troubleshooters must recognize the problems that an operator or superintendant is faced with.

B. External management concerns Within a municipal government Some of these concerns are:

Guide: Use Slide MB-7 to illustrate

"MUNICIPAL MANAGEMENT SYSTEMS IMPACTING TREATMENT PLANTS"

SLIDE MB-8 (word)

- Mayor/City Manager's office
- Engineering
- Personnel
- Purchasing
- Legal
- Finance and budget

C. There are also impacts from outside the municipal government.

"EXTERNAL RELATIONSHIPS"

SLIDE MB-9 (word)

- Labor Unions
- OSHA
- EEO Commission
- NLRB
- State Water Quality Agency
- Regional Planning Organization(s)
- EPA

V. Summary and Questions (5 Minutes)

A. Summarize Lesson

1. "MANAGEMENT BEHAVIOR SUMMARY"

SLIDE MB-10 (word)

- Management is a key to plant operations
- Troubleshooters can work *with* operators to improve management
- Management can be accomplished with management systems

LESSON OUTLINE

2. "IMPORTANT MANAGEMENT SYSTEMS INCLUDE"

   - Organization
   - Manpower
   - Training
   - Reporting
   - Maintenance
   - Safety
   - Communications

B. Use remaining time for questions and discussion

KEY POINTS & INSTRUCTOR GUIDE

SLIDE MB-11 (word)

STUDENT NOTEBOOK MATERIALS

The following materials are included in Section 9 of the Student Notebook, Management Behavior. The Notebook is distributed to students at the start of the course, and is available to them as a reference material throughout the course. Some of these materials are to be used by the instructor as an integral part of the lesson.

Index of Notebook Materials

Pages	Material	Use in Lesson
MB – 1	Management Troubleshooting Problem	Subdivision 2, Section II Problem for solution by student groups
MB – 2	Student Group Answer Sheet No. 1	Used by student groups to answer problem.
MB – 3	Student Group Answer Sheet No. 2	Same as above.
MB – 4*	Single Card Equipment Records System for a Small Plant	Reference by instructor. Subdivision 2, Section III Used to illustrate the development of a maintenance management system.
MB – 5, & MB – 6*	Maintenance Scheduling – Daily and Weekly Routines	Same as above.
MB – 7*	Sample Work Order	Same as above.
MB – 8*	Sample Inventory Card	Same as above
MB – 9 & MB – 10*	Maintenance Organization Charts	Same as above
MB – 11*	Maintenance Cost Trend Form	Same as above
MB – 12 thru MB – 14*	Example Maintenance Management System	Same as above
MB – 15*	Computer Maintenance Program	Same as above
MB 16 thru MB – 21*	Maintenance Management System Evaluation Guidelines	Subdivision 2, Section III Reviewed by class in section on evaluating maintenance systems
MB – 22	References	

Pages MB – 4 thru MB – 21 are reproduced from EPA Manual "Maintenance Management Systems for Municipal Wastewater Facilities"

MANAGEMENT TROUBLESHOOTING PROBLEM

You are a state agency field inspector and have been called out to look at a three year old activated sludge plant that treats all of its waste sludge in a two-stage digester system. Grit is removed in a degritter ahead of the primary clarifier. Primary raw sludge is concentrated in a flotation thickener. Both sludges are fed into the digester by a pump operating on a time clock.

During the past year, the chief operator had experienced frequent primary digester upsets requiring lime additions. Upon inspecting the plant, you decided to graph the results of lab tests in order to form a clearer picture of what had been happening. The graph revealed erratic volatile acid to alkalinity ratios with each upward swing of volatile acid followed by a drop in pH at which point lime was added. The total amount of lime used was 40,000 lbs at a cost of $800 for the year.

You recommended to the chief operator that he should try to correct the condition and improve digester stability, while reducing operational costs, an idea the operator took kindly to. You then began to find out what the real problem causes were so that you could develop a plan to prevent their recurrence.

By listing all of the possible causes of digester upsets, you and the chief operator concluded that some type of overloading was the basic cause. Further "brainstorming" led you to believe that frequent overloading was due to one of the following six conditions.

1. Storm infiltration
2. Withdrawing too much seed sludge.
3. New sewer connection, particularly industry.
4. An industry with an occasional heavy discharge.
5. Sludge concentration too high at times.
6. Overpumping at times.

(Please turn to the next page.)

MANAGEMENT TROUBLESHOOTING PROBLEM

Student Group Answer Sheet No 1

1. What would you look for next?

2. How would you narrow down the list of six possible causes?

3. Do you think that the problem may be due to other causes?

MANAGEMENT TROUBLESHOOTING PROBLEM

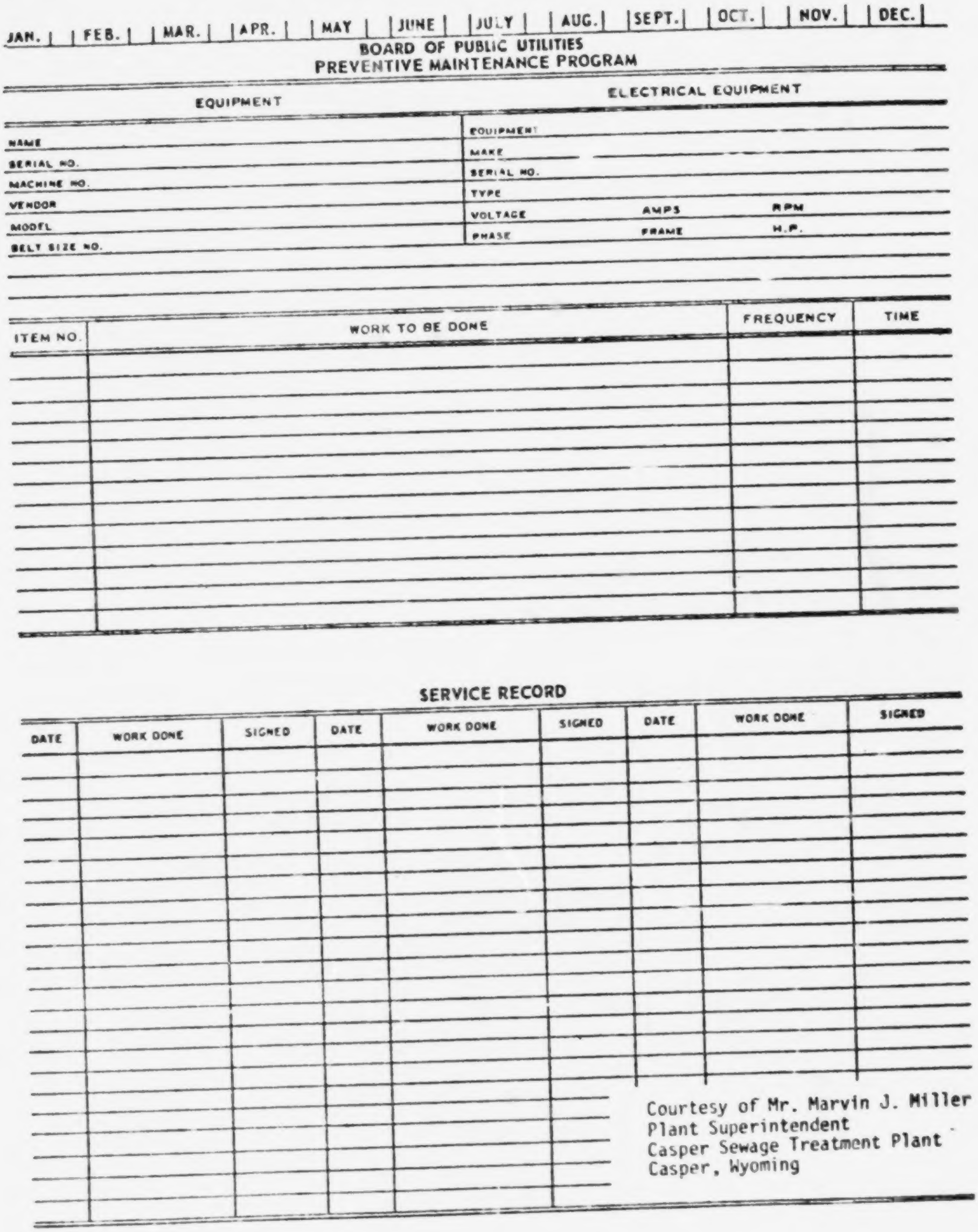
Student Group Answer Sheet No. 2

1. Which corrective action would *you* recommend as the troubleshooter in this problem?

2. How would you implement the action that you recommend?

3. Why didn't you get the right answer the first time around?

Title: Single Card Equipment Records System for a Small Plant



JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.

BOARD OF PUBLIC UTILITIES
PREVENTIVE MAINTENANCE PROGRAM

EQUIPMENT	ELECTRICAL EQUIPMENT
NAME	EQUIPMENT
SERIAL NO.	MAKE
MACHINE NO.	SERIAL NO.
VENDOR	TYPE
MODEL	VOLTAGE AMPS RPM
BELT SIZE NO.	PHASE FRAME H.P.

ITEM NO.	WORK TO BE DONE	FREQUENCY	TIME

SERVICE RECORD

DATE	WORK DONE	SIGNED	DATE	WORK DONE	SIGNED	DATE	WORK DONE	SIGNED

Courtesy of Mr. Marvin J. Miller
Plant Superintendent
Casper Sewage Treatment Plant
Casper, Wyoming

DAILY ROUTINE

NOTE:

1. SAFETY FIRST SHALL BE STRICTLY OBSERVED.
2. WORK AREAS SHALL BE KEPT CLEAN AT ALL TIMES. (WASHED & DISINFECTED)
3. ANYTHING UNUSUAL SHOULD BE REPORTED.

Wailoa and Pua Pump Stations

1. Make visual inspection
2. Check pump packing
3. Check sump pump-oil
4. Check flo-matcher water level and temperature
5. Alternate variable speed motors manually
6. Bleed air receiver tank (s)

Sub Stations

Hilo

1. Clean grating (Hose down)
2. Visual check: Pump packing-sump pump

Peninsula

1. Bleed compressor tank
2. Check sump pump

Keaukaha

1. Bleed compressor tank
2. Check sump pump

Treatment Plant

Grit Chamber

1. Grind rags and wash down
2. Visual inspect sprayer nozzles
3. Remove grit once a week

Clarifier

1. Hose down as required scum pit
2. Hose down
3. Pump out

Sludge Pump Building

1. Check sump pump
2. Visual check
3. Check sludge pump-oil level

Courtesy of Mr. Harold Sugiyama
Bureau of Sewers & Sanitation
Hilo Sewage Treatment Plant
Hilo, Hawaii

ROUTINE DUTIES — TO BE SCHEDULED BY FOREMAN

Weekly

Grit Chamber

Remove sediments and floating solids

Sludge Centrifuge Building

1. Check centrifuge torque converter oil level
2. Remove sludge (Run centrifuge with water if sludge is not removed)

Monthly

Sludge Pump Building

1. Grease air compressor bearings
2. Clean air filter

Wailoa Pump Station

1. Check compressor oil level
2. Clean air filter

General Duties

January and July

Pua Station

Grease—all bearings

1. Electric motor bearing
2. Drive shaft bearing
3. Pump bearing
4. Change packing as required (complete)
5. Exercise all valves — grease shaft
6. Wash floors as required

Sludge Centrifuge Building

Grease all bearings

February and August

Wailoa Pump Station

Grease all bearings

1. Electric motor
2. Pump drive shaft
3. Pump
4. Change packing as required (complete)
5. Exercise all valves — grease shaft
6. Wash floors as required

Courtesy of Mr. Harold Sugiyama
Bureau of Sewers & Sanitation
Hilo Sewage Treatment Plant
Hilo, Hawaii

Date ____________

Work Order No. ______________________

Location	Requested By: (Phone)	Priority:

Equipment Name	No.

☐ Inspect ☐ Replace ☐ Service

☐ Repair ☐ Overhaul ☐ Paint

Work Description

Work Performed/Comments

____
Maintenance Superintendent

Job Estimate

Labor $ ____________

Material $ ____________

Work Record

Personnel Assigned	Manhours	Date	Work Done	Parts & Materials
Total				

Work Completed By ______________________________ Date ____________

Work Accepted By ______________________________ Date ____________

SAMPLE: WORK ORDER

STOREROOM INVENTORY CARD

Item Description -

Item No. ________

Isle No. ________

Bin No. ________

Quantity Maximum ______________ Minimum ______________

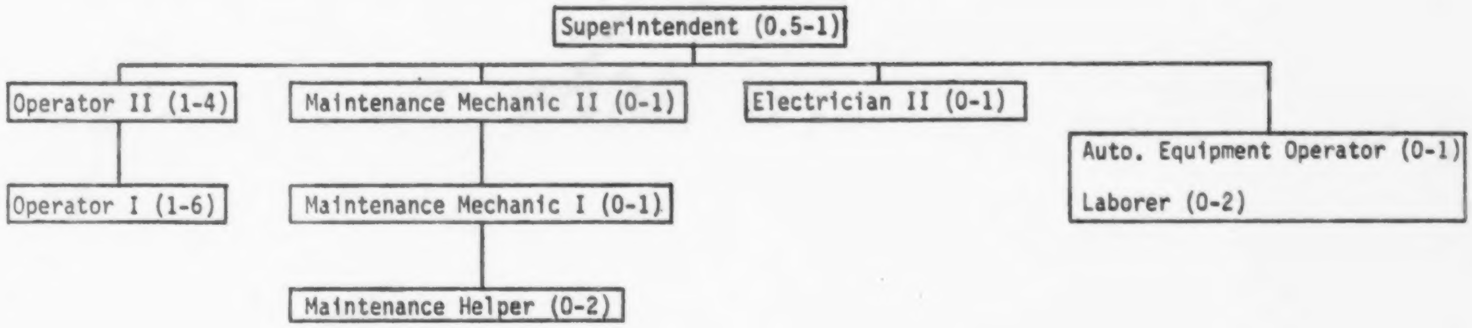
Reorder ______________

INVENTORY INFORMATION

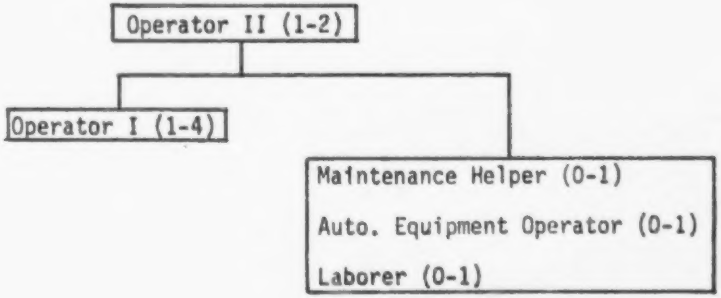
Quantity Used or Stocked	Date	Signed	Quantity on Hand	USAGE OR SUPPLY INFORMATION Usage - Work Order No. Supply - Purchase Order No.

SAMPLE INVENTORY CARD

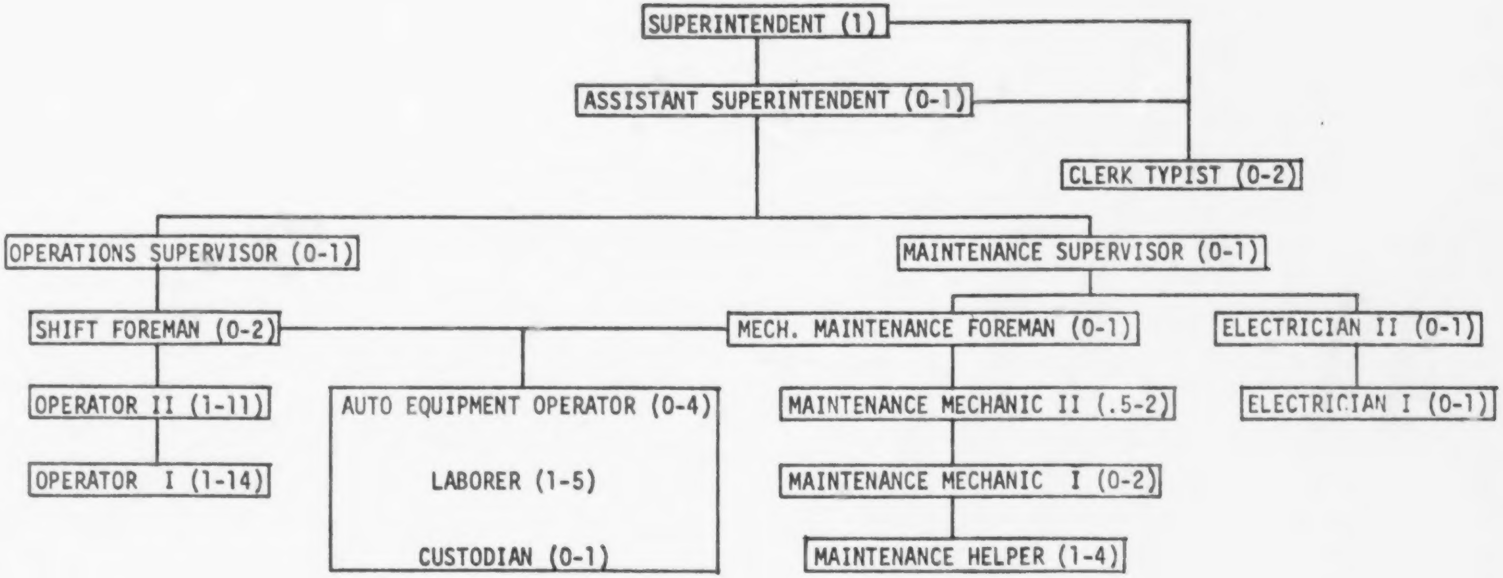
MAINTENANCE ORGANIZATIONAL CHART NO. 1


Superintendent (0.5-1)
Operator II (1-4)
Operator I (1-6)
Maintenance Mechanic II (0-1)
Maintenance Mechanic I (0-1)
Maintenance Helper (0-2)
Electrician II (0-1)
Auto. Equipment Operator (0-1)
Laborer (0-2)

MAINTENANCE ORGANIZATIONAL CHART NO. 2


Operator II (1-2)
Operator I (1-4)
Maintenance Helper (0-1)
Auto. Equipment Operator (0-1)
Laborer (0-1)

Maintenance Organizational Charts - Plant Size: 10 MGD or Less

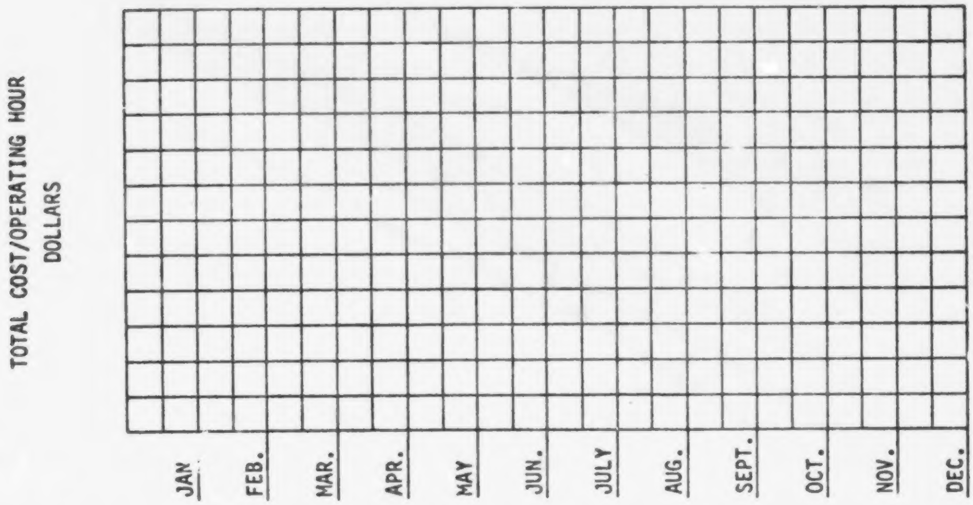

SUPERINTENDENT (1)
ASSISTANT SUPERINTENDENT (0-1)
CLERK TYPIST (0-2)
OPERATIONS SUPERVISOR (0-1)
MAINTENANCE SUPERVISOR (0-1)
SHIFT FOREMAN (0-2)
MECH. MAINTENANCE FOREMAN (0-1)
ELECTRICIAN II (0-1)
OPERATOR II (1-11)
AUTO EQUIPMENT OPERATOR (0-4)
MAINTENANCE MECHANIC II (.5-2)
ELECTRICIAN I (0-1)
OPERATOR I (1-14)
LABORER (1-5)
MAINTENANCE MECHANIC I (0-2)
CUSTODIAN (0-1)
MAINTENANCE HELPER (1-4)

Maintenance Organizational Chart - Plant Size: 10 MGD to 50 MGD

MAINTENANCE COST TREND FORM

EQUIPMENT NAME ______________________ LOCATION ____________________

I.D. NO. ______________________



MAINT. COST/HOUR $ ____ DATE	OPN. HOURS	REPAIR LABOR HOURS	PM LABOR HOURS	TOTAL LABOR HOURS	MAT'L COST	LABOR COST PER OPN. HOUR	MAT'L COST PER OPN. HOUR	TOTAL COST PER OPN. HOUR
JAN.								
FEB.								
MAR.								
APR.								
MAY								
JUN.								
JULY								
AUG.								
SEP.								
OCT.								
NOV.								
DEC.								

REMARKS ____

CORRELATION OF THE BASIC SYSTEM FEATURES INTO A WORKING MAINTENANCE MANAGEMENT SYSTEM

General

This section provides examples of maintenance management systems for various size plants. The following three examples are for a small facility, a middle size facility, and a large facility. The examples assume all facilities are properly staffed and are operating continuously. The example maintenance systems for the three size facilities are all workable systems. However, they are not intended to be rigid formats for all facilities within a given size range. In developing a system for a particular plant, a person may use any combination of the feature techniques from larger or smaller plants and may adapt them to his particular plant. Because various procedures can be used in a variety of plants, no size range has been assigned to these examples. A person preparing a new system or updating an existing system can use these examples to help develop the maintenance management system which best fits his particular plant.

Each example is broken down into the five basic features of a maintenance management system. This breakdown corresponds to this manual's format which has a separate section on each of these five basic features. This permits persons reviewing these examples of maintenance management systems to quickly refer to the appropriate section in this manual for a discussion of any item described in the examples.

Note: Included are the first three pages of an extensive section on developing maintenance management systems.

Reproduced from Chapter IX, "Maintenance Management Systems for Municipal Wastewater Facilities".

EXAMPLE MAINTENANCE MANAGEMENT SYSTEM

SMALL FACILITY

General

This example is based upon a facility with a superintendent and several operators having to perform the operations and maintenance work and keep the maintenance records.

Equipment Record System

To develop the equipment record system, each item of equipment is numbered. For a small plant, the first equipment item in the pretreatment area is given the number one. All other equipment is numbered consecutively following the wastewater flow through the facility. Multicomponent items are broken down and numbers are assigned to each component requiring any type maintenance tasks. After numbering equipment following the wastewater flow, the numbering is continued to cover all sludge handling equipment. The consecutive numbering was chosen because the number of items in a small plant is usually less than one hundred and the system is simple to apply. The following is a sample of this equipment numbering system:

Number	Equipment Description
1	Mechanically Cleaned Bar Screen
2	Comminutor
3	Raw Wastewater Pump No. 1
4	•
•	•
•	•

MIDDLE SIZE FACILITY

General

This example is for a middle size plant with a maintenance staff performing the major maintenance tasks and a clerk typist to assist in record keeping. The operators will be required to perform minor preventive maintenance on some equipment.

Equipment Record System

To develop the equipment record system, each item of equipment is numbered. All items of equipment are numbered with the equipment in a specified area or building being within a range of numbers. Multicomponent items are broken down and numbers are assigned to each component requiring any type maintenance tasks. The numbering sequence follows the flow through the plant and is continued to cover all sludge handling equipment. The following is a sample of this equipment numbering system:

Number	Equipment Description
1-25	Pretreatment Structure
1	Mechanically Cleaned Bar Screen
2	Comminutor
3	•
•	•
•	•
26-100	Primary Treatment Structure
26	Primary Sedimentation Tank No. 1
27	Manifold Valve No. 1
28	•
•	•

LARGE FACILITY

General

Because of the size and the number of personnel required to efficiently operate a large plant, its maintenance management system must be tailored for that particular plant. The following is an example using a closed system computer approach.

Equipment Record System

To develop the equipment record system, each item of equipment is numbered. The equipment numbering system assigns 1000 numbers to each major stage of the treatment plant. Multicomponent items are broken down and numbers are assigned to each component requiring any type maintenance tasks. The following is a sample of this numbering system:

Number	Equipment Description
1000	Pretreatment Structures
1100	Raw Sewage Pump Station
1110	Bar Screen Room
1111	Influent Bypass Valve
1112	Influent Diversion Gate
1113	Comminutor No. 1
1114	•
1200	Control Room
1210	Pump Motor Control Panel
1211	•
1300	Pump Room
1310	Raw Sewage Pump No. 1
1311	•

EXAMPLE MAINTENANCE MANAGEMENT SYSTEM
(Continued)

SMALL FACILITY

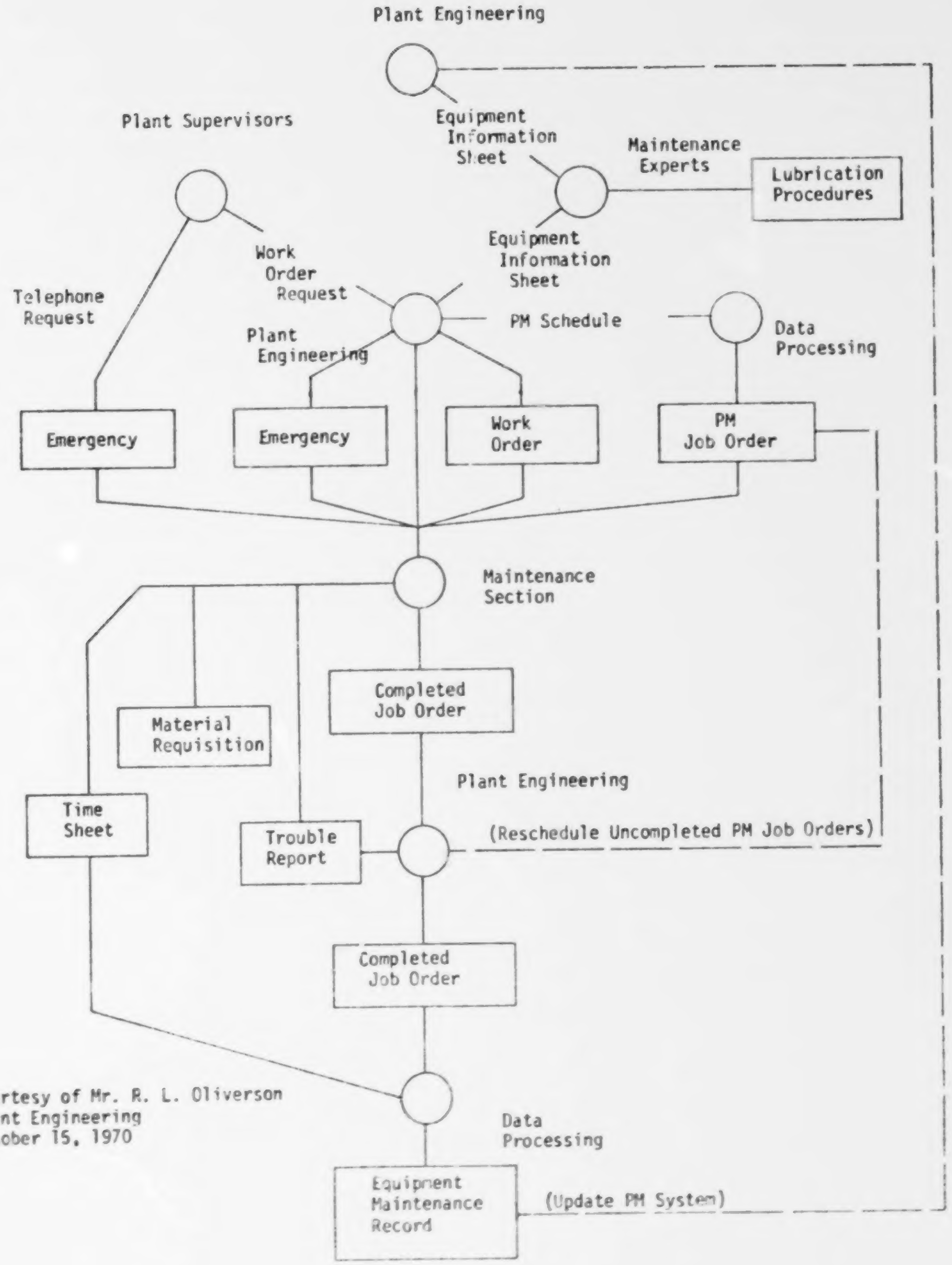
Number	Equipment Description
10	Primary Sedimentation Tank
11	Sludge Collection Mechanism
•	•
•	•
•	•
35	Aeration Tank
36	Aerator No. 1
•	•
•	•
•	•
42	Final Clarifier
43	Sludge Collection Mechanism
•	•
•	•
49	Chlorine Contact Tank
•	•
•	•
58	Raw Sludge Pump No. 1
•	•
•	•
63	Primary Digester
64	Primary Digester Stirring Mechanism
72	Sludge Drying Beds
•	•

MIDDLE SIZE FACILITY

Number	Equipment Description
101-150	Aeration Tanks
101	Aeration Tank No. 1
102	Mechanical Mixer No. 1
103	•
•	•
151-175	Final Clarifiers
151	Final Clarifier No. 1
152	Sludge Collection Mechanism
153	•
•	•
176-250	Operations Building
•	•
•	•
251-275	Chlorine Contact Tank
251	•
•	•
276-300	Sludge Thickener
276	•
•	•
301-325	Digester and Sludge Gas System
301	•
•	•
326-350	Centrifuges
326	•
•	•

LARGE FACILITY

Number	Equipment Description
2000	Primary Treatment Structure
2100	Primary Sedimentation
2110	Influent Manifold
2120	Primary Sedimentation Tank No. 1
2121	Valve No. 1
2122	•
2130	Primary Sedimentation Tank No. 2
2131	•
2132	•
2200	Boiler Room
2210	Raw Sludge and Scum, Pumping System
2211	Raw Sludge Pump No. 1
2212	•
2213	•
2220	Digested Sludge Recirculation System
2221	Sludge Recirculation Pump No. 1
2222	•
2300	Control Room
2310	Motor Control Center No. 1
2320	High Pressure Air System
2321	Compressor


Plant Engineering
Plant Supervisors
Equipment Information Sheet
Maintenance Experts
Lubrication Procedures
Telephone Request
Work Order Request
Equipment Information Sheet
Plant Engineering
PM Schedule
Data Processing
Emergency
Emergency
Work Order
PM Job Order
Maintenance Section
Completed Job Order
Material Requisition
Plant Engineering
Time Sheet
Trouble Report
(Reschedule Uncompleted PM Job Orders)
Completed Job Order
Data Processing
Equipment Maintenance Record
(Update PM System)

Courtesy of Mr. R. L. Oliverson
Plant Engineering
October 15, 1970

CLOSED SYSTEM COMPUTER MAINTENANCE PROGRAM

MAINTENANCE MANAGEMENT SYSTEM EVALUATION GUIDELINES

This section is to aid persons developing maintenance management systems by providing a checklist for evaluating a proposed system and to aid treatment plant management in evaluating an existing maintenance management system. The evaluation guidelines are broken down into the five basic maintenance features considered essential to a maintenance management system. A maximum of two hundred (200) points have been allotted to each feature, thus a maximum score of one thousand (1000) points is possible. In reviewing a system, the evaluator must remember these guidelines apply to all types and sizes of treatment plants. Due to the range of plant sizes and their complexities, no minimum passing score has been given. The purpose of these guidelines is to aid in locating problem areas so they may be corrected or improved. An individual using these evaluation guidelines will generally find the maintenance system he is analyzing does possess most of the features outlined in the Guidelines. However, there will probably be many qualifications accompanying each positive response to the questions in the Guidelines. This is true because the features of many maintenance systems are either incomplete or are incapable of performing their intended function. Each question in the Evaluation Guidelines should be carefully weighed and given a rating commensurate with the feature's ability to perform its role in the total maintenance management system.

EQUIPMENT RECORD SYSTEM

EVALUATION GUIDELINES	MAX. RATING	YOUR RATING
1. Do you have an equipment numbering or other identification system to aid in locating and identifying all major items of equipment?	20	
2. Do you have a system for maintaining nameplate data and other essential information on all major equipment items within the treatment system?	50	
3. Does your maintenance record system provide for listing preventive maintenance (PM) tasks, giving their frequency and recording the PM work performed?	30	

EQUIPMENT RECORD SYSTEM
(CONTINUED)

EVALUATION GUIDELINES	MAX. RATING	YOUR RATING
4. Does your maintenance record system provide for recording corrective maintenance work performed?	20	
5. Does your maintenance record system provide for recording such information as maintenance manhours, spare parts or components used in repair and name of individual performing each job?	30	
6. Does your maintenance record system provide for recording all maintenance related costs and can these costs be readily compiled for use in maintenance budget preparation?	30	
7. Are miscellaneous maintenance related documents such as as-built drawings, construction specifications and photos, shop drawings and manufacturers' literature properly filed and indexed and readily available to maintenance staff?	20	
TOTAL	200	

PLANNING AND SCHEDULING

EVALUATION GUIDELINES	MAX. RATING	YOUR RATING
1. Is some form of schedule chart or priority list provided to assist maintenance supervisors in controlling maintenance tasks?	20	
2. Do you plan and schedule preventive maintenance (PM) tasks for all major equipment items within the treatment system?	30	

EVALUATION GUIDELINES	MAX. RATING	YOUR RATING
a. Are PM frequencies based upon manufacturers' recommendations and by inspection?	10	
b. Does the existing maintenance organization permit the proper scheduling of required PM and take into account the corrective maintenance demands on the maintenance force?	10	
3. Are potential corrective maintenance tasks adequately considered in maintenance planning?	20	
4. Do you have a work order system that satisfies the treatment system's maintenance requirements?	30	
5. Are manpower management techniques used effectively to obtain maximum utilization?	30	
6. Do you have some form of labor standards to assist in preparing accurate work estimates for repetitive maintenance jobs?	30	
7. Have you contracted for maintenance tasks beyond the capability of your staff and determined the availability of this support?	20	
TOTAL	200	

STOREROOM AND INVENTORY SYSTEM

EVALUATION GUIDELINES	MAX. RATING	YOUR RATING
1. Have you provided a storeroom or storage area to assist in controlling the flow of spare parts, components and maintenance supplies?	40	
2. Have you reviewed manufacturers' recommendations and studied each major equipment item's maintenance requirements to determine what maintenance items should be maintained?	40	
a. Have you developed a system to monitor quantities of all maintenance items kept in stock?	20	
b. Have you established minimum and maximum quantities for all maintenance items kept in stock?	20	
c. Do you have a purchase order system that adequately controls the procuring of maintenance items?	20	
3. Do you have system for locating a given item in the storeroom?	20	
4. Do you have a catalog or index system to assist in identifying and locating a given item in the storeroom?	20	
5. Do you have a storeroom ticket or withdrawal slip to use when maintenance items are taken from stock?	20	
TOTAL	200	

MAINTENANCE ORGANIZATION & PERSONNEL

EVALUATION GUIDELINES	MAX. RATING	YOUR RATING
1. Do you have a maintenance organization chart that satisfies treatment system requirements?	30	
2. Is your maintenance organization chart reviewed and updated as required?	20	
3. Do you have job descriptions for each job title within your maintenance organization?	30	
4. Are job descriptions kept up to date and made available to maintenance personnel as required?	20	
5. Prior to initiating any program to correct deficiencies in a maintenance job, is a thorough analysis of this job performed?	50	
6. Do you have a maintenance training program that satisfies the maintenance objectives of the treatment system?	50	
TOTAL	200	

COST AND BUDGETS FOR MAINTENANCE OPERATIONS

EVALUATION GUIDELINES	MAX. RATING	YOUR RATING
1. Are maintenance costs broken down by maintenance categories such as preventive maintenance, corrective maintenance and major repairs or alterations?	50	
2. Do you have a system of cost codes or charge numbers for allocating labor and materials to specific maintenance jobs?	40	

EVALUATION GUIDELINES	MAX. RATING	YOUR RATING
3. Do you have a system for recording the maintenance cost history of all major equipment items?	30	
4. Do you have a system for compiling cost information for use in budget preparation and maintenance cost studies?	50	
5. Do you have a system for recording contract maintenance costs so they can be used in preparing maintenance budgets?	30	
TOTAL	200	

Persons using these Evaluation Guidelines should follow up the evaluation with a review of the areas receiving the lowest ratings. It should be remembered that an apparent weak area may be due to another system feature performing poorly and pulling the weak area down.

The questions in the Evaluation Guidelines are grouped into the five basic maintenance features. Individuals can review the section of the manual which discusses each basic feature when they find deficiencies in the maintenance system they are analyzing. The information contained in the manual should assist persons in correcting the weaknesses in their maintenance management system.

It should be recognized that several of the questions in the Evaluation Guidelines deal with items that are absolutely essential to the success of any maintenance management system. These critical items include an equipment identification system, planning and scheduling preventive maintenance tasks, control of spare parts and supplies, and a system for preparing maintenance budgets. Maintenance management systems that receive low ratings in any of these critical areas should be considered deficient and appropriate corrective actions taken.

REFERENCES – MANAGEMENT BEHAVIOR

Maintenance Management Systems for Municipal Wastewater Facilities. USEPA Office of Water Programs Operations, 1973.

Estimating Staffing for Municipal Wastewater Treatment Facilities. USEPA Office of Water Programs Operations, 1973.

Hayes, R.B., Operator's Guide to Management and Supervision. Stevens, Thompson & Runyan, Inc., Portland, 1975.

Bittel, What Every Supervisor Should Know. McGraw Hill.

American Management Association. Supervisory Effectiveness – A home study course.

Water Pollution Control Federation. Manual of Practice No. 1. Safety in Wastewater Works.

Emergency Planning for Municipal Wastewater Treatment Facilities. USEPA.

Equal Employment Opportunity Commission. Affirmative Action and Equal Employment. Guidebook for Employers.

Handy Reference Guide to the Fair Labor Standards Act. U.S. Department of Labor.

Water Pollution Control Federation. Manual of Practice No. 10, Uniform System of Accounts for Wastewater Utilities.

Water Pollution Control Federation. Manual of Practice No. 12, The Public Relations Handbook.

LESSON – ACTIVATED SLUDGE

Instructor Overview of Lesson

Entry Level Behavior: Students will have had University training in Sanitary Engineering, waste treatment and/or related sciences or equivalent in experience and training. Some field experience in inspecting treatment facilities, but none in operating waste treatment facilities.

As a prerequisite to this course, it is recommended that the student will be able to –

1. Identify treatment plant process units.
2. Describe treatment plant process units and equipment in technical terms.
3. Identify and explain the purpose of components of treatment plant process units, how they work and why they are important to the overall process.
4. Describe the normal operating procedures for treatment plant process unit components.
5. Identify when treatment plant process units are not operating properly.

Instructor Objectives: The principal instructor objectives for this lesson are:

1. To review basic concepts in activated sludge process design and operation.
2. To present visual views of activated sludge process units, equipment, and observations of problems.
3. To present basic problem causes and to use the Process of Troubleshooting to correct operational problems.
4. To provide the students with the opportunity to troubleshoot and analyze realistic problems.
5. To review actual troubleshooting case histories.
6. To provide a general understanding of the operation and troubleshooting of package treatment plants.

References: Note list of references included with Student Notebook materials.

Total Length of Lesson: 7 hours, 15 minutes for 9 lesson subdivisions.

LESSON OVERVIEW

Subdivision Title & Time	Major Student Objectives	Key Points & Content	Approach	Materials
1. Introduction to Activated Sludge Process	1. List process objectives, system components, and controllable process variables for activated sludge.	1. Versatility of activated sludge.	1. Combine lecture, slides, and student discussion.	1. Word slides and key.
90 Minutes	2. Describe characteristics of sludge quality.	2. Sludge quality as a sign of performance.	2. Use chalkboard to record student inputs.	2. Student Notebook materials; cases, diagrams, checklists, and supplemental information.
	3. Identify concepts for activated sludge control, their advantages and disadvantages.	3. Control concepts.	3. Use of Notebook materials.	3. EPA Pamphlet Series.
	4. Identify sampling points and data.	4. Control strategy relationships.		
	5. Describe common activated sludge variations.	5. Variations of activated sludge.		
2. Process Evaluation Procedures	1. Make observations and identify problems in relation to primary clarifiers, pumps and meters, aeration tanks and final clarifiers.	1. Determine problems through visual inspection.	1. Present slide series using key.	1. Slide Series and Key.
45 Minutes		2. Control of return sludge.	2. Provide opportunity for student discussion.	2. EPA Pamphlet Series.
			3. Instructor to ask questions of students to have *them* identify slide contents.	

LESSON OVERVIEW

Subdivision Title & Time	Major Student Objectives	Key Points & Content	Approach	Materials
3. Applying the Process of Troubleshooting	1. Identify causes of high BOD and suspended solids.	1. Use of The Process of Troubleshooting.	1. Instructor leads class discussion of activated sludge problems.	1. Word slides and key.
	2. Identify visual observations and data needed to troubleshoot activated sludge.	2. Controllable and uncontrollable factors.	2. Instructor seeks and records student inputs on identifying problem causes.	2. Picture slides portraying problem situations.
1 Hour	3. Describe plant problems related to hydraulics, and sludge characteristics.	3. Problem causes.	3. Use selected slides as visual statements of problems, with additional data provided by the instructor.	3. "Operator's Pocket Guide to Activated Sludge," Pamphlets.
	4. List steps to correct activated sludge problems, and apply The Process of Troubleshooting.	4. Sludge characteristics.		4. Process of Troubleshooting Chart.
4. All You Really Wanted To Know About Activated Sludge	1. Supplement knowledge of activated sludge.	1. Details of activated sludge lesson which need to be reviewed.	1. Students submit written questions.	1. Student questions.
30 Minutes	2. Discuss specifics of activated sludge previously not clear.		2. Instructor reviews and prepares answers, discussion.	

LESSON OVERVIEW

Subdivision Title & Time	Major Student Objectives	Key Points & Content	Approach	Materials
5. Troubleshooting – Hamsborough Treatment Plant 45 Minutes	1. Describe process at an activated sludge plant.	1. Description of Hamsborough Plant and problem.	1. First part of problem presented in Student Notebook and with slides.	1. Slides and key.
	2. Analyze and sample for analysis at an activated sludge plant.	2. Plant tour.	2. Students analyze problem.	2. Problem Statement, Part 1, and answer sheet, Student Notebook.
	3. Use The Process of Troubleshooting to solve activated sludge problems.	3. Analyze Hamsborough situation.	3. Additional information provided by handout.	3. Problem Statement, Part II, distributed by instructor.
	4. List and prioritize alternative solutions.	4. Review of solutions of Hamsborough problem.	4. Student groups analyze problem.	
			5. Class reviews and discusses alternative solutions.	
6. Troubleshooting – Pullman Treatment Plant 45 Minutes	1. Describe conditions at a plant subject to extreme variations in loading.	1. Description and operational history of Pullman Washington treatment plant.	1. Use Student Notebook materials to present problem to the class groups.	1. Student Notebook materials presenting problem, solution and answer sheet.
	2. Analyze and troubleshoot process control problems.	2. Discussion of influent flow pattern.	2. Students analyze problem using answer sheet.	
	3. Identify practical modifications to control activated sludge.	3. Student analysis of problem.	3. Group report on approaches to the problem.	
	4. Describe use of respiration rate as a control approach.	4. Solution actually implemented at Pullman, use of respiration rate to control process.	4. Instructor presents approach actually used.	

AS.-IV

LESSON OVERVIEW

Subdivision Title & Time	Major Student Objectives	Key Points & Content	Approach	Materials
7. Activated Sludge Case Histories	1. Analyze and identify procedures to correct the following activated sludge problems: hydraulic surging, flow imbalance, improper weir placement, return sludge flow control, inadequate mixing and blocked clarifiers.	1. Six problems on operations of activated sludge treatment plants.	1. Instructor shows slides of problem, provides background information.	1. 26 slides on activated sludge problems, and slide key.
45 Minutes		2. Value of quick troubleshooting assistance.	2. Students discuss problem.	
			3. Instructor presents actual solution.	
8. Small Activated Sludge Plants	1. Identify package treatment plant features and configurations.	1. Plant configurations, features and components.	1. Instructor uses prepared slides, audio tape, and Notebook materials.	1. WPCF "Extended Aeration Training Course MTM-01" including slides, audio tape cassette, text of slides.
45 Minutes	2. List process control observations for package treatment plants.	2. Importance of solids wasting in package plants.	2. Utilize experience of students through student discussion.	2. Student Notebook diagrams and tables.
	3. Describe the expected performance of extended aeration and contact stabilization plants.	3. Process of Troubleshooting and Troubleshooting Guide.		
	4. Use the Process of Troubleshooting to identify and correct problems in small plants.			
9. Summary, Questions and Answers	1. To reinforce student objectives from other lessons.	1. Summary of materials presented on activated sludge.	1. Respond to questions.	1. Lesson plans and materials, Subdivisions 1-8.
			2. Discuss topics of interest.	
30 Minutes			3. Summarize activated sludge lesson.	

LESSON – ACTIVATED SLUDGE

Presentation Options for Course Director

The lesson ACTIVATED SLUDGE is one of the major subject areas covered in this course. It contains nine (9) subdivisions, and, as written, requires a presentation time of 7 hours, 15 minutes. This lesson could be expanded or shortened, depending on the needs of the student group. However, in relation to a total course time of 28 to 40 hours, the existing time of presentation is appropriate. If the lesson needs to be significantly shortened for any reason, it is suggested that subdivision 5, or subdivision 6, which are troubleshooting problems be deleted, thereby providing only one troubleshooting problem instead of two. However, the minimum time for presenting the significant points of this lesson is 6 hours, and it should not be attempted in any time less than that.

On the other hand, there is much material in this lesson that could easily be expanded. If the course director has available to him additional time, it is possible to expand the time in this lesson up to as much as 15 or 20 hours.

Some of the presentation options are as follows:

Subdivision 1 – Introduction to Activated Sludge Processes: The existing 90 minute lesson is sufficient for students with the proper level entry background for the course. The lesson may be supplemented with additional slides showing various activated sludge treatment components and processes. In addition, greater detail can be used to go into the EPA Pamphlet Series, "Operational Control Procedures for the Activated Sludge Process." Therefore, it is possible to expand this subdivision well beyond 90 minutes. However, if an expansion is undertaken, the subdivision should be subdivided and breaks should be provided between the various components of the expanded subdivision.

Subdivision 2 – Process Evaluation Procedures: This is another important subdivision on the foundation of troubleshooting the Activated Sludge process. This subdivision may be supplemented with the slide-tape series provided by the National Waste Treatment Center in Cincinnati, A.W. West. The instructor may wish to use those materials directly, by using the audio tape along with the slides, or may wish to use the script and text of the tape as provided by EPA.

Subdivision 3 – Applying the Process of Troubleshooting: This subdivision provides a series of basic problem solving techniques to be used in troubleshooting problems for activated sludge. In Section VII, at the end of the subdivision, there is a 15 minute series of three problems that are presented to the class. This section can be expanded both in time, and in the number of problems, if it is felt to be desirable by the course director.

Subdivision 4 – All You Really Wanted to Know About Activated Sludge: This subdivision, which is 30 minutes, is included as a breather in the presentation of detailed technical materials on Activated Sludge, and gives the class a chance to catch up with the instructor and with themselves. It may be tempting for the course director to exclude this subdivision, particularly if time is short. However, that temptation should be resisted. It is necessary at this juncture in the lesson to depart from formal lesson plan materials and to allow time for questions and discussion.

Subdivision 5 – Troubleshooting – Hamsborough Treatment Plant: and *Subdivision 6 – Troubleshooting – Pullman Treatment Plant:* Each of these two subdivisions are 45 minutes in length, thereby allowing one and one-half hours for student problem solving activities within the overall Activated Sludge lesson plan. If anything, this time alloted for student problem solving is on the low side in relation to the total length of the lesson. If time is extremely short, one of these two subdivisions could be excluded. However, if time is sufficient, it is recommended that both of these subdivisions be used and possibly expanded. In addition, the Course Director and instructor should feel free to substitute another major problem at an Activated Sludge Treatment Plant if that problem would make an interesting case study and if there are sufficient materials available to present the problem to the class. In any regard, problems must be used that allow the students to participate in an exercise involving the use of The Process of Troubleshooting.

Subdivision 7 – Activated Sludge Case Histories: This lesson subdivision has proven to be extremely useful and informative because of the practical nature of the problems presented, and because it allows for student participation. It is an important part of the lesson and should be retained.

Subdivision 8 – Small (Package) Activated Sludge Plants: For many presentations of this course, Subdivision 8 is an extremely important part of the Activated Sludge lesson. Experience shows that many of the treatment plants encountered by field personnel and experiencing problems are of the package treatment plant variety. If, for some reason, this is not the case in the particular setting in which the course is being given, this subdivision can be excluded. Conversely, it may be desirable to expand this lesson beyond the 45 minutes allotted. If that is the case, the course director should obtain the training materials on extended aeration from the Water Pollution Control Federation that are cited in the subdivision under training materials. From these materials, additional lesson material can be developed to complement that which is already provided, and to complement the overall focus of the course on troubleshooting.

Subdivision 9 – Summary, Questions and Answers: Because of the length of this lesson, a formalized time period of Summary, Questions and Answers is necessary, and this subdivision should be included in any presentation.

LESSON PLAN – SUBDIVISION 1

TIME: 90 MINUTES

Title: Introduction to Activated Sludge Processes

Instructor Objectives: To review basic concepts in activated sludge process design and operations. To orient the class to terminology used in the lesson to assure effective communication between the instructors and the class.

Student Objectives: As a result of this lesson subdivision, students will be able to do the following:

1. Describe the process objectives in activated sludge
2. List the major components of an activated sludge system
3. List the controllable process variables for activated sludge
4. Describe the characteristics of sludge quality
5. Define the relationship between settled sludge volume (SSV) and settled sludge concentration (SSC)
6. List and identify the common concepts for activated sludge control
7. Identify the advantages and disadvantages of each of the common concepts for activated sludge control
8. Describe the relationships between the different process control strategies
9. Identify sampling points and data for activated sludge process evaluation
10. List and describe the common variations of the activated sludge process

Training Materials:

16 slides, word slides and diagrams, and slide key

Control Cases, Student Notebook page AS-1

Checklist for process evaluation, Student Notebook pages AS-2 thru AS-9

Process Flow diagrams, Student Notebook page AS-10 thru AS-13

Supplemental Information on Control Concepts, Student Notebook pages AS-14 thru AS-18

EPA Pamphlet Series, "Operational Control Procedures for the Activated Sludge Process"

Classroom Set-Up:

A normal classroom set-up will be required. Students should be seated with their student groups

35 mm carousel slide projector with remote controls

Large screen (8 ft x 10 ft)

Chalkboard or easel

Pointer

Subdivision Schedule:

TIME	SUBJECT
0 – 10 Minutes	Introduction
10 – 20 Minutes	Process Objectives in Activated Sludge
20 – 30 Minutes	Characteristics of Sludge
30 – 50 Minutes	Common Concepts for Activated Sludge Control
50 – 65 Minutes	Control Strategy Relationships
65 – 75 Minutes	Data and Sampling for Process Evaluation
75 – 85 Minutes	Common Variations of the Activated Sludge Process
85 – 90 Minutes	Questions and Discussions

Subdivision Approach:

The instructor should combine a lecture approach and the use of slides with student discussion and opportunity for student input

Sections I & II, instructor should use chalkboard to present the lesson schedule, and to record student inputs

Instructor should be careful to define all new terms

Section V, class is referred to and uses Student Notebook page AS-1, Control Cases

Section VIII, class is referred to and uses Student Notebook pages AS-10 thru AS-13, flow diagrams

Class discussion should be stimulated and encouraged at all times during the lesson subdivision

LESSON OUTLINE

I. Introduction (10 Minutes)

A. Note that activated sludge has become *the* major process in secondary treatment, and it is the process that troubleshooters in most areas are likely to encounter sooner or later. Some of the characteristics of activated sludge include:

1. "THE ACTIVATED SLUDGE PROCESS"
   - Varies in size from the smallest to the largest plants
   - Offers operational flexibility – several modes available
   - Produces high quality effluents
   - Requires process controls

B. Lesson Objectives – This lesson is designed to involve the student in the operational and troubleshooting aspects of the activated sludge process, specifically

"LESSON OBJECTIVES/TROUBLESHOOTING ACTIVATED SLUDGE"

- Review process control concepts
- Identify common problems and their causes
- Define procedures for correcting operating problems
- Experience problem solving

C. Lesson Schedule

D. Student Notebook Materials – Refer students to Section 10 of the Student Notebook. Indicate that these materials will be used throughout the lesson

II. Process Objectives in Activated Sludge (10 Minutes)

A. Process Objectives

1. Ask the question "What are the process objectives of activated sludge?" Have the class give this answer in one sentence

KEY POINTS & INSTRUCTOR GUIDE

Use Slide AS 1-1 to introduce this discussion.

SLIDE AS 1-1 (word)

Key Point: Stress the versatility and universality of activated sludge, from the smallest package plants up to and beyond metropolitan plants of 100 mgd.

Use the next slide to illustrate.

SLIDE AS 1-2 (word)

Because this is a long lesson, the instructor should indicate (by chalkboard or other means) the schedule that will be followed.

Guide: Instructor should use the chalkboard to record student input on this section.

LESSON OUTLINE

2. Instructor's Definition. Read the following and put the key words on the chalkboard

   The process objectives of activated sludge are to *convert* soluble biodegradable pollutants to *settleable solids* to produce a *clarified effluent low* in suspended solids (TSS) and dissolved biodegradable pollutants (BOD)

B. Ask the question "What are the major components in an activated sludge system?"

   1. List the class response on the blackboard
   2. Show Slide AS 1-3 and discuss briefly the necessity of each component and why it is important

      a. Slide AS 1-3 is a simple flow diagram of the conventional activated sludge process, which shows the following components

         1. Raw sewage inflow
         2. Primary settling and sludge removal
         3. Aeration tanks and air inflow
         4. Secondary settling tanks and effluent
         5. Return activated sludge
         6. Waste activated sludge

C. Ask the question "Which of the process variables are controllable?"

   1. Note that the rest of the lesson will deal with the controllable variables
   2. Class response to this question should note the following variables:

      a. Air supply rate
      b. Return sludge rate
      c. Waste sludge rate

III. Characteristics of Sludge (10 Minutes)

A. Define good sludge and have the class participate Response should note that the quality of the sludge should be such that it will remove dissolved BOD, settle well, and produce a clear effluent

KEY POINTS & INSTRUCTOR GUIDE

Note: Key words in italics.

SLIDE AS 1-3 (diagram)

Guide: List variables on chalkboard. Refer to slide AS 1-3 and show where these variables come into play.

LESSON OUTLINE

B. "SLUDGE QUALITY – ACTIVATED SLUDGE"

GOOD	BAD
- Slow Settling	- Settles very fast (5 minutes)
- Concentrates uniformly in 30 to 60 minutes	- Settles too slowly, does not concentrate
- Clear supernatant	- Cloudy & turbid, straggler floc, ash
- Flocculent	- Granular
- Deep tan or light brown	- Light tan, dark brown or black

C. Relative Settling Rates

Note that the qulity of the sludge is important and that most tests stress quantity. Settling characteristics can indicate future impending problems and is an indicator of process condition

1. The diagram shows curves for settling of three sludges
   a. Young sludge (poor quality) settling volume from 1,000 to 750 in 60 minutes
   b. Good quality sludge – settling volume from 1,000 to 200 in 60 minutes
   c. Old sludge – settling volume from 1,000 to 100 in 20 minutes
2. Sludge Volume Index – SVI

   The sludge volume index is a parameter used to indicate settling in a 30 minute period. A concentration curve is more useful because it shows the nature of the sludge settling, and can go beyond 60 minutes in cases where that is useful

D. Settled Sludge Volume (SSV) and Settled Sludge Concentrations (SSC)

1. Note that SSV stands for Settled Sludge Volume and represents the amount of sludge that settles in a given amount of time in a settleometer

KEY POINTS & INSTRUCTOR GUIDE

SLIDE AS 1-4 (word)

Key Point: These characteristics of sludge quality become easily recognizable signs of performance.

Guide: Use Slide AS 1-5, Settling Diagram, to illustrate the settling characteristics of good and poor sludge.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
2. SSC stands for Settled Sludge Concentration and is expressed in percent. A calculation can be made from the SSV and the centrifuge concentration of the sludge, expressed in percent and abbreviated as ATC	
3. Curve of Settled Sludge Concentration shows the differences between poor sludges and a good sludge	Show Slide AS 1-6, SSC curves.
4. SSC curve and SSV curve relate to each other in an inverse manner, as shown on Slide AS 1-7	SLIDE AS 1-7 (diagram)
5. For more information on these parameters, and other concepts that will be discussed, students should be referred to EPA materials prepared by Al West – "Operational Control Procedures for the Activated Sludge Process," EPA Cincinnati. Information can be obtained through the O&M branches of EPA regional offices	
IV. Common Concepts for Activated Sludge Control (20 Minutes)	Guide: The concepts and terminology in this section may be new to many of the students. The instructor should be careful to be sensitive to the background level of the class on this subject. Do not use technical terms or abreviations without first defining them.
A. Note to the students that process control for activated sludge has become a highly technical field. There are a variety of control concepts, some simple, some quite complex. A few of the more common concepts are presented in this section	
B. Food to Microorganism Ratio (F/M)	
1. Definition "F/M RATIO" $F/M = \frac{\text{lb BOD Removed/day}}{\text{lb MLSS under aeration}}$	SLIDE AS 1-8 (word) Guide: Define MLSS.
2. Advantages. F/M balances food with the "bugs" or the mass of biological solids under aeration	
3. Disadvantages a. Time consuming b. Does not consider solids in the clarifier c. BOD information is 5 days late	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
4. Loading Range a. 0.2 – 0.5 lb BOD removed per lb MLSS per day b. Best results are found when a 5 – 7 day moving average is used rather than day to day values 5. Control mechanism for F/M is the waste sludge	
C. Mean Cell Residence Time (MCRT) 1. Definition The MCRT is defined as time in days that an average cell remains in the aeration basin and is calculated by dividing the pounds of mixed liquor solids by the pounds of solids wasted per day	
"MEAN CELL RESIDENCE TIME (MCRT)"	SLIDE AS 1-9 (word)
$$\text{MCRT} = \frac{\text{lb MLSS}}{\text{lb (XS + Final Effl.) SS}}$$	
Control for MCRT: Waste Sludge 2. Advantages a. Requires only a single laboratory measurement for suspended solids b. Easy to implement 3. Disadvantages a. Doesn't consider the amount of organic load coming into the plant b. Measures only sludge under aeration 4. The MCRT chosen for given plant must be determined experimentally. The most conventional plants operate with an MCRT of 5 – 8 days while extended aeration may be as long as 15 – 30 days 5. Control mechanism for MCRT is Waste Sludge	

LESSON OUTLINE

D. Sludge Retention Time (SRT)

1. Definition

SRT is calculated by dividing the total pounds of mixed liquor solids in the aeration basin and the clarifier by the pounds of solids wasted per day (waste activated sludge plus effluent suspended solids).

"SLUDGE RETENTION TIME (SRT)"

$$SRT = \frac{\text{Total Solids in System}}{\text{Solids Wasted/Day}}$$

Control for SRT: Waste Sludge

2. Advantages
   - a. Requires only single laboratory measurement
   - b. Easy to implement
3. Disadvantages
   - a. Fails to consider the organic load on the system
   - b. Doesn't designate how the solids are distributed between the final clarifier and aeration basin
4. Control decision should be based on a 5 or 7 day moving average rather than instantaneous day to day values
5. Control Mechanism for SRT is Waste Sludge

E. Sludge Age (SA)

1. Definition

Sludge age is defined as the pounds of suspended solids in the aeration system divided by pounds of suspended solids in the primary effluent per day

2. Sludge age is an impirical control parameter developed by Gould as a control for his treatment plant. There is no theoretical basis to support the validity of this control concept and it will not be discussed further

KEY POINTS & INSTRUCTOR GUIDE

SLIDE AS 1-10 (word)

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

F. Constant MLSS

1. Definition

   This strategy calls for determining the best MLSS concentration that produced good effluent and maintaining that number constant

2. Advantages
   - a. Control is simple
   - b. One analysis is necessary at the same time each day

3. Disadvantages
   - a. Doesn't consider variations in organic or volumetric load
   - b. Does not consider solids in clarifier
   - c. Requires influent conditions to be fairly constant
   - d. Samples must be taken at the same point and same time each day

4. Concentration is controlled by varying the waste rate

G. Respiration Rate (RR or Oxygen Uptake Rate)

1. Respiration rate is defined as the milligrams of oxygen used per gram of solids under aeration per hour. Most often it is collected in the aeration tank near the point where the sludge goes to the secondary clarifier. Other uses are:
   - a. Return sludge diluted with final effluent
   - b. Return sludge diluted with primary effluent

   "RESPIRATION RATE (RR)" — SLIDE AS 1-11 (word)

RR = MG O_2/Gr MLSS/Hr

Control for RR: Return Activated Sludge rate, and/or change of mode

LESSON OUTLINE

2. Advantages
   a. Rapid measurement of influents of waste characteristics on activated sludge
   b. May be used to indicate presence of toxic waste
   c. Permits determination of oxygen demand at various points in the aeration basin
3. Disadvantages
   a. Several samples must be collected, analyzed and evaluated
   b. Test procedure requires sophisticated equipment
   c. Experience is needed to interpret the results
4. Representative respiration rates for mixed liquor going to the secondary clarifier generally range between 8 and 20 milligrams O_2/gram MLSS/hour
5. To control the respiration rate:
   a. Return activated sludge is the best control mechanism
   b. A process mode change may be appropriate to control RR
6. Additional information on the use of respiration rate may be found in the EPA slide tape series XT-43 "Dissolved Oxygen in Activated Sludge," by F.J. Ludzack, available on loan from EPA's National Training Center in Cincinnati, Ohio

H. Sludge Quality

1. Sludge quality was discussed previously and the characteristics of good and bad sludge quality were reviewed. Note that all of the above process control strategies have a single objective – achieving and maintaining good sludge quality and producing a highly purified effluent

KEY POINTS & INSTRUCTOR GUIDE

Note: Student Notebook pages AS-14 thru AS-18 contain materials on control concepts for student reference.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
2. Sludge quality concepts were pioneered by Mallory in the thirties and have been simplified, advanced and improved by West. A pamphlet series is available through EPA training centers describing this system	
3. Basic tools for controlling under this concept are a laboratory centrifuge and a settleometer, also a device for determining the blanket depth in the secondary clarifier	
V. Control Strategy Relationships (15 Minutes) Note: This section is designed to bring out the relationships between the different activated sludge control strategies	Guide: In this section, the instructor should maximize class participation and discussion.
A. Ask the class to discuss the similarities in most of the process control strategies presented in the previous section – i.e., F/M, MCRT, SRT, Sludge Age, Constant MLSS, RR	
1. The common feature in most control strategies is solids within the system	
B. Ask the class – in what way do solids become part of the control strategies?	
1. Most of the control strategies are based on a solids balance within the system	
2. First step of each strategy – determine the solids balance that yields the best effluent	
3. The control objective then becomes to maintain the solids inventory constant at the level that produces the best effluent	
C. Present the class with the following three control cases – For each case, read the statement and ask the class to indicate which direction they would expect each control parameter to change under the stated conditions	Refer students to Notebook page AS-1 where control cases are listed.

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

D. Case I: Assume that the hydraulic and organic loads to the aeration basin remain constant. Settleometer test results indicate that the sludge is beginning to settle more slowly and return sludge concentrations are decreasing

1. Indicate below what the expected change in each parameter would be:
   - a. F/M
   - b. MCRT
   - c. Respiration rate of the MLSS
2. Indicate below the control actions that would probably be required
   - a. Return sludge flow rate
   - b. Waste sludge rate
3. Results of Case I – Parameter Changes
   - a. F/M would increase as mass in the aeration basin decreases
   - b. MCRT would decrease
   - c. The sludge would tend to settle more slowly in the settleometer test and the aeration MLSS as measured by centrifuge would tend to decrease. The RR at the effluent of the aeration basin would tend to increase as would the RR of the return sludge-final effluent mixtures. These effects are probably caused by excessive wasting of activated sludge
4. Control Actions
   - a. Decrease the sludge waste rate
   - b. Most likely increase return sludge rate

E. Case II: Assume that the hydraulic load to the aeration basin remains constant and that the organic load increases. Assume that no changes have been made in return rates or in wasting practices

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

1. Indicate below the expected change in each parameter:
    - a. Sludge settling rate
    - b. Sludge blanket depth
    - c. F/M
    - d. MCRT
    - e. Respiration rate of the MLSS
    - f. Aeration basin D.O.
2. Indicate below the control actions that would probably be required
    - a. Return sludge rate
    - b. Waste sludge rate
    - c. Air supply rate
3. Results of Case II – Parameter Changes
    - a. Sludge settling rate would decrease
    - b. Sludge blanket level would increase in the final clarifier
    - c. F/M would increase
    - d. MCRT would remain about the same
    - e. Respiration rate would increase
    - f. D.O. in the aeration basin would decrease
4. Control Actions
    - a. Increase the return sludge flow rate
    - b. Decrease waste sludge rate.
    - c. Increase air supply rate

F. Case III: Assume that the hydraulic flow to the aeration basin increases while the organic load remains constant

1. Indicate below what the expected change in each parameter would be:
    - a. MLSS concentration
    - b. F/M
    - c. MCRT
    - d. Respiration rate of the MLSS
    - e. Sludge settling rate
    - f. Sludge blanket depth

2. Indicate below the probable control actions that would be required:
    a. Sludge return rate
    b. Waste sludge rate
3. Results of Case III – Parameter Changes
    a. MLSS would decrease
    b. F/M would increase
    c. MCRT would decrease
    d. RR of MLSS would increase
    e. Sludge settling rate in the settleometer would decrease
    f. Sludge blanket level would rise
4. Control Actions
    a. Increase return sludge
    b. No change in wasting

VI. Data and Sampling for Process Evaluation (10 Minutes)

A. Schematic of Activated Sludge Process

Use Slide AS 1-12 for much of this section. Slide shows simple schematic of activated sludge process.

B. Using Slide AS 1-12, discuss the principal sampling points to monitor process performance for activated sludge. These should include:

1. Aerator influent
2. Primary clarifier influent
3. Final effluent
4. Return activated sludge
5. Waste sludge
6. Aeration basin
7. Final clarifier

LESSON OUTLINE | **KEY POINTS & INSTRUCTOR GUIDE**

C. Ask the class for their input on what control parameters should be tested or observed at each sampling location

D. Checklist – Activated Sludge Process Evaluation

Refer students to Student Notebook pages AS-2 thru AS-9.

1. Developed by EPA, National Waste Treatment Center
2. Note that checklist is keyed to nomenclature in the EPA – Al West pamphlets on activated sludge process control
3. Have students review checklist on their own time, if they have questions, bring them up later in the lesson

VII. Common Variations of the Activated Sludge Process (10 Minutes)

Four activated sludge variations will be discussed by showing flow diagrams and briefly reviewing their normal operating characteristics

A. Conventional Activated Sludge

1. Flow diagram – discuss the general flow pattern

SLIDE AS 1-13

2. Operating Characteristics

Refer to Student Notebook page AS-10 which contains flow diagram and operating characteristics.

   a. Aeration basin detention time 4-8 hours
   b. Loading 30-40 lbs BOD/1,000 ft^3
   c. F/M 0.2-0.5
   d. Air 750-1,000 ft^3/lb BOD
   e. Sludge age 4-6 days
   f. Overflow rate 800-1,000 gpd/ft^2
   g. Clarifier detention time 1-3 hours
   h. Return sludge flow 15-75%
   i. Waste flow 1-2%
   j. Waste solids 0.4-0.6 lb/lb BOD

B. Step Aeration

1. Flow diagram – discuss the general flow pattern and the possibility of feeding primary effluent to various points in the tank to even out the loading

SLIDE AS 1-14

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
2. Operating Characteristics	Refer to Student Notebook page AS-11
a. Detention time 3-8 hours	
b. Loading 40-60 lbs BOD/1,000 ft^3	
c. F/M 0.2-0.5	
d. Air 500-700 ft^3/lb BOD	
e. Return Sludge Flow 20-75%	
C. Contact Stabilization	
1. Flow diagram. Describe the major features of contact stabilization noting that the contact tank is normally smaller and allows shorter contact time for the waste. The process that takes place in this tank is normally adsorption. The flow then passes to the secondary clarifier and the sludge that is returned from the clarifier goes to a sludge reaeration tank where absorption generally takes place at a higher rate than in the contact tank.	SLIDE AS 1-15
2. Operating Characteristics	
a. Detention time 4-8 hours (Reaeration)	Refer to Student Notebook page AS-12
b. Loading 35-70 lbs BOD/1,000 ft^3 (combined volume)	
c. F/M 0.2-0.5 (contact tank)	
d. Air 750-1,500 ft^3/lb BOD	
e. Return sludge flow 50-150%	
f. Detention time aeration contact tank 0.5-1.5 hour	
D. Extended Aeration	
1. Describe the process noting the general absence of a primary clarifier and also the fact that these types of plants are more commonly used in a package plant configuration or the oxidation ditch type plant	SLIDE AS 1-16
2. Operating Characteristics	
a. Detention time 16-24 hours	Refer to Student Notebook page AS-13
b. Loading 10-15 lbs BOD/1,000 ft^3	
c. F/M 0.01-0.08	
d. Air 2,000-2,500 ft^3/lb BOD	
e. Overflow rate 300-600 gpd/ft^3	
f. Return sludge flow 50-200%	
VII. Questions and Discussions (5 Minutes)	Guide: Use remaining time for questions and discussions

LESSON PLAN – SUBDIVISION 2

TIME: 45 MINUTES

Title: Process Evaluation Procedures

Instructor Objectives: To introduce and present to the students views of various activated sludge process units, including typical equipment used in the activated sludge process. To identify visual clues and observations on typical activated sludge problems.

Student Objectives: As a result of this lesson subdivision, students will be able to do the following:

1. Identify problems associated with primary clarifiers and primary effluents
2. Visually observe pumps and meters for indicators of operational problems
3. Observe the operating characteristics of aeration tanks
4. Inspect and make observations on final clarifiers

Training Materials:

Slide Series of 51 Slides, with Slide Key

EPA Pamphlet Series, "Operational Control Procedures for the Activated Sludge Process"

The slide series included as support to the lesson was prepared by A.W. West, USEPA National Waste Treatment Center, Cincinnati, Ohio As such the slides flow as a continuous story leading from influent of the aeration basin to the final clarifier overflow. Instructor may use this as is, or make comments based on personal knowledge and experience. Brief notations are made for each slide.

Classroom Set-Up:

A normal classroom set-up will be required. Students should be seated with their student groups

35 mm carousel slide projector, with remote controls

Large screen (8 ft x 10 ft)

Chalkboard or easel

Pointer

Subdivision Schedule:

Within the 45 minute time period, the following schedule should be observed in presenting the lesson plan outline

TIME	SUBJECT
0 – 10 Minutes	Clarifier Problems
10 – 35 Minutes	Visual Indicators, Process Equipment
35 – 45 Minutes	Questions and Discussion

Subdivision Approach:

The instructor is to follow the lesson outline by presenting the slide series, using the slide key

The instructor should provide opportunity to the students for discussion and participation in the presentation

Many of the slides have the notation in the lesson outline: Guide:
Question. This signifies that the instructor is to *not* describe the slide, but rather ask a question of the class and allow the students, in effect, to describe the slide. As much of this method of presentation as possible should be employed

Many of the slides lend themselves to considerable discussion by the class. This should be encouraged by the instructor

Prior to presenting this material, the instructor must review the slides and become familiar with them

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
I. Introduction Instructor should note that the slides show a sequence running from the influent through the aeration basin and then to the secondary clarifier with indicators and information relevant to each of these portions of the plant noted in sequence	Note: Be sure slide projector is set up and slides are in focus. Slides to be used in this series are AS 2-1 thru AS 2-51.
II. Review of Problems Associated with Influent and Primary Clarifier (10 Minutes)	SLIDES
A. Check pH of raw influent	AS 2-1
B. Primary effluent appears black. Ask question "What would normally cause this?" (digester supernatant)	AS 2-2. Guide: Question.
C. Improper loading -- primary clarifier (they should be pumping sludge)	AS 2-3
D. Scum and Solids – primary clarifier (more frequent skimming is needed)	AS 2-4
E. Equalization tank for industrial load which was supposed to have had screening (It didn't!)	AS 2-5
F. *What is the problem here?* (Inadequate aeration)	AS 2-6
G. Primary clarifier distribution box with digester supernatant	AS 2-7
H. This is a safety item. It is obvious that the cord is too short on the DO probe. (This is an old sludge – note by the color)	AS 2-8
III. Visual Indicators – Process Equipment and Problems (25 Minutes)	SLIDES Key Point: Many plant operational problems can first be determined thru visual inspection.
A. Flow rates, pumps and meters 1. "OBSERVATIONS" Meters Aeration Tanks Clarifiers	AS 2-9 (word)

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE SLIDES
2. "RECORD DISCHARGE RATES" • Primary Effluent to Aerator • Return Sludge from Clarifier • Excess Sludge to Waste • Air to Aerators	AS 2-10 (word)
3. Stopwatch is used to check totalizer at receiver. Note meter fluctuations. *What may cause this?*	AS 2-11 Guide: Question.
4. Good meter control, well defined readout	AS 2-12
5. *What causes this fluctuation?*(pump station operation)	AS 2-13 Guide: Question.
6. Return sludge valves located in yard, meter is in building, denotes poor design	AS 2-14 Guide: Contrast these two slides showing poor,
7. Return sludge meter and controller shown on the same panel	AS 2-15 good design.
8. Remotely controlled return sludge valve	AS 2-16 Note: Control of return sludge is something a troubleshooter should look for.
9. Remotely controlled vari-drive on return sludge pump. (*Note that it is a good idea to exercise these types of drives frequently over their entire range to prevent mechanical problems)*	AS 2-17
10. Separate waste sludge pump, good design	AS 2-18
B. Aeration tank observations	
1. "AERATION TANK OBSERVATIONS"	AS 2-19 (word)
2. *Contact stabilization* plant with no primary clarifier. What are some of the problems? (grit and rags)	AS 2-20 Guide: Question.
3. One of the problems here shows when the operator has no primary clarifier. (This slide has been shown before – in the Pretreatment Lesson)	AS 2-21
4. What is probably causing the dead spots in this aeration tank? (Possibly plugged diffusers which need cleaning)	AS 2-22 Guide: Question.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
	SLIDES
5. Poor control of air due to speed changes being the only aeration control possible. At one-half speed only one-fourth the air efficiency is accomplished	AS 2-23
6. Turbine aerators with sparge below	AS 2-24
7. Sparge turbines get good mixing with reduced air	AS 2-25
8. This type of diffuser may cause a "core" and possible short circuiting. (Ask for student input on their experiences with this problem.)	AS 2-26 Guide: Question.
9. Cross-row diffusers give good mixing – no core	AS 2-27
10. Empty tank showing cross-row diffusers	AS 2-28
11. Tank surface with spiral flow pattern	AS 2-29
12. Swirl pattern type tank shown empty (same plant as previous slide)	AS 2-30
13. Closeup of the same diffusers which shows a wide range of aeration capabilities	AS 2-31
C. Tank foam significance	
1. This foam is white, what does it indicate? (young sludge and low solids)	AS 2-32 Guide: Question.
2. The tan color to this scum designates what condition? (old sludge and possibly Nocardia, which is a bacteria)	AS 2-33 Guide: Question.
3. This may appear to be young sludge, actually it also has grease and oil mixed with it. (This is an oxidation ditch)	AS 2-34
4. Same plant as previous slide (shows oil waste or denitrified old sludge)	AS 2-35
D. Final clarifier observations	
1. "FINAL CLARIFIER OBSERVATIONS"	AS 2-36 (word)

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE SLIDES
2. This is good effluent. The inspector should try to determine how the operator achieves this. Use a sludge blanket finder to measure depth	AS 2-37
3. Note that very little sludge pickup occurs at the outside and inside of this collection system. Problems develop sometimes with this type of clarifier because solids settle around the outside periphery, go septic and rise, going out in the effluent. A piece of stiff rubber attached to the outside of this arm will prevent that kind of collection. Suction devices should also have been extended to the outside to pick up sludge	AS 2-38
4. Same clarifiers above. Closeup of scrapers	AS 2-39
5. Proper scraper and suction device	AS 2-40
6. This is a closeup of the same unit	AS 2-41
7. This is a rectangular clarifier, what is the problem here? (poor scum baffle)	AS 2-42 Guide: Question.
E. Final clarifier notations	
1. Example of good operation	AS 2-43
2. This is an example of what happens when plant operation is poor, however, more indicators are necessary before the total problem can be defined	AS 2-44
3. This shows ash in the final effluent, what might it be due to? (old sludge)	AS 2-45 Guide: Question.
4. These clumps may be due to what? (too old sludge or denitrification or chemical dosage)	AS 2-46 Guide: Question.
5. Closeup of clumps, what is the solution? (increase return sludge and wasting)	AS 2-47 Guide: Question.
6. Straggler floc, what may cause this? (Usually a transition from too young a sludge going to normal sludge age. The condition is intensified in shallow tanks)	AS 2-48 Guide: Question.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE SLIDE
7. In this case the settling was ideal, what may cause this appearance? (Hydraulic overload)	AS 2-49 Guide: Question.
8. This is an example of classic bulking. Too young a sludge. Solutions might be to reduce dissolved oxygen to 1 mg/l or less, reduce waste, reaerate, or increase sludge age	AS 2-50
9. This shows good effluent even though the sludge is bulky. However, in a bulking situation there is the danger of losing all of the solids	AS 2-51
IV. Questions and Discussion (10 Minutes)	
A. Time should be taken to review any material that was presented, answer questions, and allow for overall class discussion	

LESSON PLAN – SUBDIVISION 3

TIME: 1 HOUR

Title: Applying the Process of Troubleshooting

Instructor Objectives: To present the basic causes of operational problems in the activated sludge process, and to use the Process of Troubleshooting to analyze and correct such problems.

Student Objectives: As a result of this lesson subdivision, students will be able to do the following:

1. Identify common causes of high BOD and suspended solids in activated sludge
2. List the types of data that may be needed to solve activated sludge problems
3. Describe problems related to plant hydraulics
4. Classify sludge related causes of activated sludge operating deficiencies
5. Describe the visual observations, analyses and settling characteristics of various sludge conditions
6. List basic steps that can be taken to correct activated sludge problems
7. Identify and attempt to correct conditions of sludge bulking
8. Apply the Process of Troubleshooting to common activated sludge problems

Training Materials:

Slide Series of 7 word slides, and key

Six picture slides repeated from subdivision 2
  Slides AS 2-32, 51, 33, 46, 34, 45

Pamphlets, "Operator's Pocket Guide to Activated Sludge" Parts I & II

Chart, The Process of Troubleshooting, Student Notebooks

Student Notebook p AS-19, Additional Problem Information

Classroom Set-Up:

A normal classroom set-up will be required. Students must be seated with their student groups.

35 mm carousel slide projector, with remote controls

Large screen (8 ft x 10 ft)

Chalkboard or easel

Pointer

Subdivision Schedule:

Within the 60 minute time period, the following schedule should be observed in presenting the lesson plan outline:

TIME	SUBJECT
0 – 5 Minutes	Introduction
5 – 10 Minutes	Identifying Problem Causes
10 – 15 Minutes	Identifying Data Needs
15 – 30 Minutes	Interpreting Data to Determine Causes
30 – 40 Minutes	Solutions to Common Problems
40 – 45 Minutes	Causes and Cures of Sludge Bulking
45 – 60 Minutes	Applying the Process of Troubleshooting

Subdivision Approach:

This subdivision calls for a good deal of student participation and input, in addition to the instructor's following of the lesson outline.

It is suggested that this subdivision be handled as class-instructor discussion. Rather than presenting pat answers, the instructor should attempt to lead the class in providing the information needed to identify and resolve the problem causes discussed. Six general causes of problems which are typically found in activated sludge systems are identified, and the techniques for solving these problems are given. Group discussion is an effective technique to achieve the identification of the problem cause. The instructor must carefully control the discussion and must pose leading questions to assure that the responses desired are obtained. The chalkboard is a useful tool for this discussion approach.

In Section VII, Applying the Process of Troubleshooting, the instructor is to use selected 35 mm slides from subdivision 2, as visual statements of problems and have the class recommend causes and corrections for these problems. The instructor should use the four-man groups which have been pre-formed for the course to work together in solving the problem. Since visual indicators only will be provided, the instructor should be prepared to feed the class additional information as it is requested by the group(s). Appropriate data are provided for each situation represented by the slides at the end of this subdivision

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
I. Introduction (5 Minutes)	
A. The basic problem that brings the operator into conflict with regulatory people is the fact that the final effluent is not meeting the NPDES permit requirements for suspended solids and/or BOD	Guide: Illustrate with Slide AS 3-1.
"PERFORMANCE TEST — ACTIVATED SLUDGE"	Slide AS 3-1 (word)
Does the final effluent meet NPDES requirements? • Suspended Solids • BOD	
B. No two activated sludge systems are alike. Experience in operating and troubleshooting activated sludge plants seems to be the best teacher	
1. By using the Process of Troubleshooting, activated sludge problems may be analyzed and corrected systematically	
2. The objective of this lesson is to probide tools which can help the troubleshooter determine the cause of a problem, and thereby assist him in solving that problem	
C. The process of troubleshooting	Refer students to the Process of Troubleshooting Chart in the Student Notebook.
1. The first step is to determine that a problem exists and to identify what it is	
2. If final effluent monitoring indicates that the BOD or suspended solids exceed allowable levels — the problem has been identified, although the cause certainly has not been	
3. From that point, follow the basic steps of the Process of Troubleshooting	Guide: Illustrate the Process of Troubleshooting by using this slide.
"SOLVING A PROBLEM WITH THE PROCESS OF TROUBLESHOOTING"	Slide AS 3-2 (word)
Step 1: Analyze and learn Step 2: Formulate alternative solutions Step 3: Corrective actions, trial and error Step 4: Observe and test Step 5: Long range implementation	Note: Have the students follow each step on the Process of Troubleshooting Chart in their Student Notebooks.

LESSON OUTLINE

II. Identifying Causes of High BOD and/or Suspended Solids (5 Minutes)

- A. Ask the class to identify possible causes of poor activated sludge performance
- B. Generalize the responses into specific categories
- C. Generally, the types of causes can be categorized into two groups, as follows:
  - 1. Causes which the troubleshooter or operator can deal with
    - a. Hydraulic overload or imbalance
    - b. Sludge control
  - 2. Causes that can't be controlled
    - a. Organic overload
    - b. Toxics

  "CAUSES OF POOR ACTIVATED SLUDGE PERFORMANCE"

  - Controllable factors
    Hydraulic
    Sludge
  - Uncontrollable factors
    Organic load
    Toxics
- D. Note that the next step is to identify the data needed to formulate the most likely causes and most effective solutions

III. Identifying Data Needs (5 Minutes)

- A. Ask the class to name the samples, tests and data required to generate a brief list
- B. Note the inputs as they are presented
- C. The list may include the following elements
  - 1. Flow information
  - 2. Constituents in the waste
  - 3. Visual observations
  - 4. System related information

KEY POINTS & INSTRUCTOR GUIDE

Guide: This section should be handled as a discussion with the students. List the responses on the chalkboard.

Illustrate this point with the following slide.

AS 3-3

Guide: The instructor should conduct this as a discussion. Record class inputs using the chalkboard.

LESSON OUTLINE

IV. Interpreting Data to Determine Possible Problem Causes (15 minutes)

  A. Hydraulic problems

    1. Hydraulic overload – if a comparison of flows received at the plant with design data shows that it is grossly overloaded, chances are the plant operator cannot do that much about it and the problem lies further up in the authority chain to develop a plan for preventing excess inflow and infiltration and/or authorized plant expansion. This becomes a design consultant's job; not one for the operator

    2. Imbalance – a problem of multiple tanks fed from the same influent channel. If individual metering is available, this may help the operator in reaching a solution, or solids balances may be helpful in determining the amount of flow going to various tanks. This can be done with a laboratory centrifuge or by gravimetric means

    3. Short circuiting – this can be best detected by using dyes or tracers

    4. Flow variability, Predictable Types – industrial wastes that are discharged on a cyclic basis. Plant operation can be set up to cope with these types of fluctuations if the time of day when the flows will be received at the plant is known and quantities can be determined

    5. Surging – pump stations create this type of a flow pattern. Problems may be traced to improperly sized pumps and it is possible to solve this, in some cases, by throttling pump discharges or installing cycling devices, such as a float control that will control over a narrow band of the operating range

    6. Ask class to identify other causes of surging and hydraulic variability and use the class to help identify solutions

KEY POINTS & INSTRUCTOR GUIDE

Guide: Discuss each of these problem causes.

Guide: Summarize hydraulic problems with the following slide:

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
"ACTIVATED SLUDGE — HYDRAULIC PROBLEMS" • Overload • Internal imbalance • Short circuiting • Flow variability • Surging	Slide AS 3-4 (word)
B. Sludge related causes	
1. Means of identifying sludge related problems	Guide: Use the following slide to discuss means of identifying sludge related problems.
"MEANS OF IDENTIFYING SLUDGE RELATED PROBLEMS" • Visual observations color foam • Analysis of control parameters F/M, MCRT, RR, MLSS • Settling results	Slide AS 3-5 (word)
2. Most common sludge problems	Guide: Use slide to illustrate.
"COMMON SLUDGE PROBLEMS" • Sludge age too old too young	Slide AS 3-6 (word)
• Sludge quantity too little too much	Guide: In the following four sections (3-6) ask the class to identify the expected characteristics of the sludge for each sludge problem type.
3. Sludge too old a. Visual observations — dark shiny leathery foam, dark color from brown to black b. Analyses — MLSS and MCRT probably high. F/M probably low. RR probably less than twelve milligrams O_2/gram MLSS/hour c. Settling rate — probably fast	
4. Sludge too young a. Visual observations — white foam	

   b. Analyses – MLSS, MCRT low; F/M and RR high

   c. Settling rate – very slow, fluffy in appearance

5. Too little sludge
   a. Visual observations – similar to young sludge

   b. Analyses – MLSS low, F/M and RR high, turbidity increasing in final effluent

   c. Settling rate – slow. Compaction does not improve dilution

6. Too much sludge
   a. Visual observations – similar to old sludge. High sludge blanket in clarifier, ash in final effluent

   b. Analyses – MLSS high, F/M low, RR low, MCRT very long

   c. Settling rate – slow. Settling and concentration improve if sample is diluted

   "SLUDGE PROBLEM IDENTIFIERS"

Problem	**Visual**	**MLSS**	**F/M**	**RR**	**Settling**
1. Too old	dark foam	high	high	low	fast
2. Too young	white foam	low	low	high	slow
3. Too little	light	low	high	high	slow
4. Too much	dark	high	low	low	slow

V. Solutions to Common Activated Sludge Problems (10 Minutes)

   A. Because activated sludge is a complex treatment system, there are no "simple" solutions. Some of the basic steps that can be taken to deal with the problem causes discussed in Section IV are presented as follows:

   B. Hydraulic problems

Guide: Use Slide AS 3-7 to summarize these different sludge characteristics.

Slide AS 3-7 (word)

For more details on specific sludge characteristics and on troubleshooting activated sludge in general, refer students to "Operator's Pocket Guide to Activated Sludge," Parts I and II, which should be included as part of course materials.

Guide: Throughout this section, the instructor should seek class input on how to solve common activated sludge problems.

LESSON OUTLINE

1. Hydraulic overload
    a. Problem is external to plant
    b. Reduction of inflow and infiltration is necessary
2. Flow imbalance
    a. Good metering is necessary
    b. Resetting of weirs and flumes, and their gauges may be needed
3. Short circuiting
    a. New flow patterns may have to be established in aeration tanks
    b. Flexible valve and pipe alignment is useful
4. Flow variability
    a. Industrial ordinances and controls
    b. Flow equalization
5. Surging
    a. Pump controls need to be installed, repaired, or reset

C. Sludge related problems

1. Old sludge
    a. Reduce aeration detention time
    b. Keep sludge return rates high
2. Young sludge
    a. Decrease waste flow — move toward contact stabilization
    b. Increase aerator detention time
3. Too little sludge
    a. Decrease sludge wasting
    b. Decrease waste flow
    c. Increase detention time
4. Too much sludge
    a. Increase wasting
    b. Reduce detention time
    c. Keep the sludge return rate high

KEY POINTS & INSTRUCTOR GUIDE

Guide: Use the chalkboard to record student input on to correct sludge problems.

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

VI. Causes and Cures of Sludge Bulking (5 Minutes)

A. Definition of bulking sludge – sludge which occupies more than normal volume in the clarifier resulting in solids loss over the clarifier weir into the plant effluent

B. Bulking may be caused by

1. Hydraulic problems
2. Biological causes

C. Identifying bulking

1. Sludge particles have filaments that can be identified with a microscope
2. However, the characteristics of bulking sludge can usually be determined from sludge behavior

D. Short-term solutions

1. Chemicals
2. Lower D.O.
3. Apply hydrogen peroxide
4. Use chlorine as a last resort
5. Lower pH using alum

E. Long-term solutions

1. Characterize influent and correct causes
2. Equalize waste flow
3. Increase return rate
4. Change process mode of sludge reaeration, possibly use digester supernatant in a reaeration tank (Kraus process)

VII. Applying the Process of Troubleshooting (15 Minutes)

A. Instructions to instructor for presenting three (3) problems to the class

1. Each problem is shown by using 2 slides that were used originally in subdivision 2. For each problem, each group should:

Guide: Problems are to be solved by preselected groups of four students.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
a. Identify the problem b. Determine the likely cause c. Offer alternative solutions	
2. The instructor is given additional information, with which to answer questions if he desires. This information for each problem is provided on Student Notebook page AS-19	
3. Stress that each group should approach the problems by applying the Process of Troubleshooting	
4. Allow about 4 minutes for each problem	
B. Problem 1	
1. The aeration tanks of a 40 mgd conventional activated sludge plant look like this. The plant has the capability to return sludge in the range of 10 to 100% of influent flow	Show Slide AS 2-32
2. The final clarifiers look like this. There are eight clarifiers, each with a separate return sludge pump	Show Slide AS 2-51
3. Additional information	Refer students to Student Notebook page AS-19.
a. F/M = 0.6	
b. Settling: 5 min 950 30 min 750 60 min 580	
c. Q = 40 MGD	
d. MLSS = 1,200 mg/l	
e. RAS = 4,200 mg/l	
f. Reaeration is possible	
g. Return rate = 40%	
C. Problem 2	
1. This is a 1 MGD plant with return sludge of 20 to 70%	Show Slide AS 2-33
2. There is only one final clarifier, it looks like this	Show Slide AS 2-46

LESSON OUTLINE

3. Additional information
    a. MCRT = 14 days
    b. F/M = 0.13
    c. MLSS = 4,200 mg/l
    d. RAS = 12,600 mg/l
    e. Settling: 5 min 630
    30 min 360
    60 min 330
    f. There has been no sludge waste in 7 days

D. Problem 3

1. This is an extended aeration plant with a design flow of 0.5 MGD
2. The final clarifier looks like this
3. Additional information
    a. MCRT = 15 days
    b. F/M = 0.07
    c. Q = 0.3 MGD
    d. RAS = 3,480 mg/l
    e. MLSS = 2,400 mg/l
    f. % RAS = 160%
    g. Settling: 5 min 405
    30 min 140
    60 min 115

E. Problem Answers – After about 12 minutes, have class provide solutions to problems 1 to 3. Seek agreement to arrive at a common answer for each case

1. Problem 1 – This is a case of a young sludge, low solids
2. Problem 2 – This is a case of an old sludge
3. Problem 3 – This is a sludge with grease and oil, that may look like a young sludge (It settles much faster)

VIII. Questions for Following Subdivision

Before adjourning class, have students use index cards to write down questions they may have at this point in the lesson

These questions will be reviewed by the instructor, and answered in the next subdivision, "All you really wanted to know about activated sludge."

KEY POINTS & INSTRUCTOR GUIDE

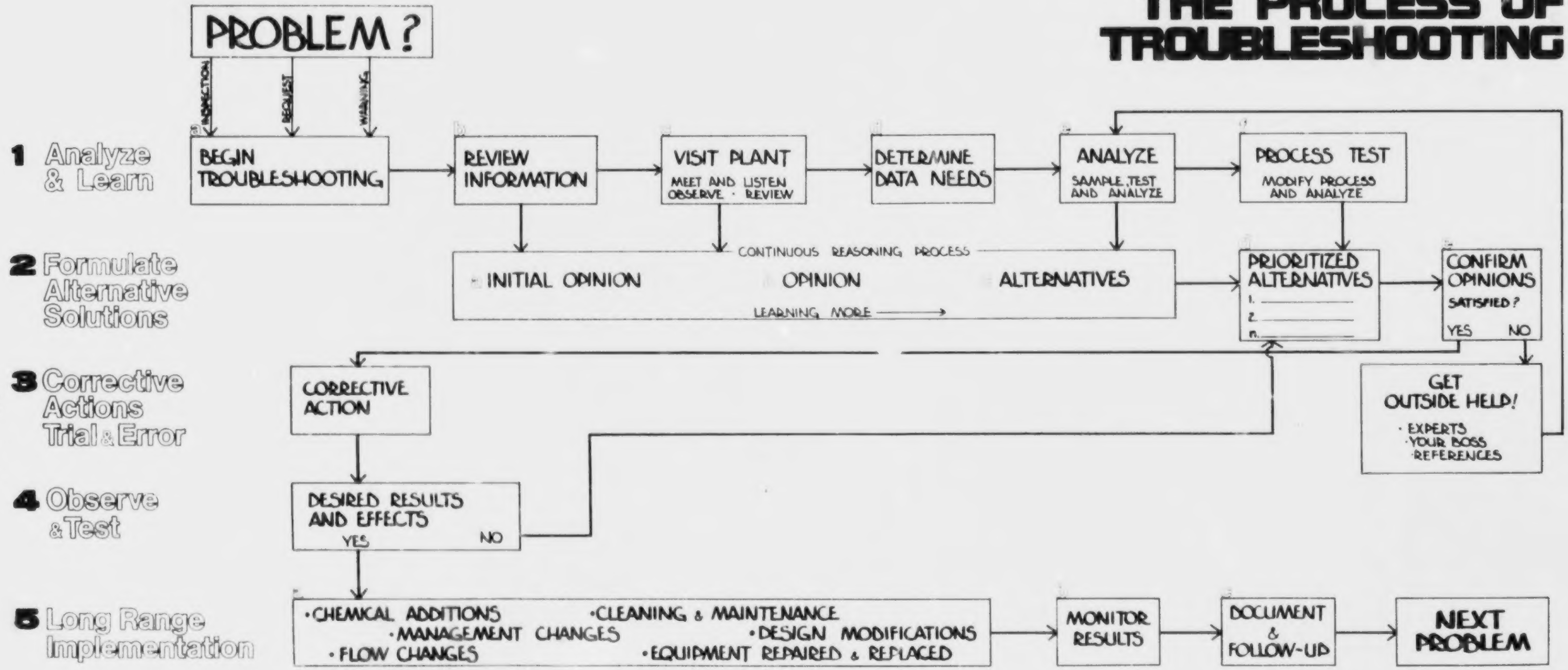
Refer to Student Notebook page AS-19.

Show Slide AS 2-34

Show Slide AS 2-45

Refer to Student Notebook page AS-19

THE PROCESS OF TROUBLESHOOTING


1 Analyze & Learn
2 Formulate Alternative Solutions
3 Corrective Actions Trial & Error
4 Observe & Test
5 Long Range Implementation
PROBLEM?
INSPECTION
REQUEST
WARNING
BEGIN TROUBLESHOOTING
REVIEW INFORMATION
VISIT PLANT
MEET AND LISTEN
OBSERVE · REVIEW
DETERMINE DATA NEEDS
ANALYZE
SAMPLE, TEST AND ANALYZE
PROCESS TEST
MODIFY PROCESS AND ANALYZE
CONTINUOUS REASONING PROCESS
INITIAL OPINION
OPINION
ALTERNATIVES
LEARNING MORE
PRIORITIZED ALTERNATIVES
1.
2.
n.
CONFIRM OPINIONS
SATISFIED?
YES
NO
GET OUTSIDE HELP!
· EXPERTS
· YOUR BOSS
· REFERENCES
CORRECTIVE ACTION
DESIRED RESULTS AND EFFECTS
YES
NO
· CHEMICAL ADDITIONS
· CLEANING & MAINTENANCE
· MANAGEMENT CHANGES
· DESIGN MODIFICATIONS
· FLOW CHANGES
· EQUIPMENT REPAIRED & REPLACED
MONITOR RESULTS
DOCUMENT & FOLLOW-UP
NEXT PROBLEM

HS 3-12

ACTIVATED SLUDGE

LESSON PLAN – SUBDIVISION 4 **TIME: 30 MINUTES**

Title: All You Really Wanted to Know About Activated Sludge

Instructor Objectives: To provide the students with an opportunity to pose specific questions on activated sludge, and to allow time for detailed answers and discussion. To tie together "loose ends" in the students' understanding of the activated sludge process prior to the assignment of detailed troubleshooting problems.

Student Objectives: As a result of this lesson subdivision, students will be able to do the following:

1. Supplement their knowledge of activated sludge by obtaining answers to questions about those aspects of the process that they don't fully understand
2. Discuss the specifics of the activated sludge process that previously were not totally comprehended
3. Proceed to working on solving troubleshooting case studies with confidence in their knowledge of the activated sludge process

Training Materials:

To preserve the informal nature of this subdivision, no prepared training materials are used other than questions submitted by the students at the conclusion of an earlier subdivision within the activated sludge lesson

Classroom Set-Up:

A normal classroom set-up will be required. Students should be seated with their student groups

Chalkboard or easel

Pointer

Subdivision Schedule:

There is no formal schedule to this subdivision

Subdivision Approach:

At the conclusion of Subdivision 3, the instructor asks the students to submit questions on the activated sludge process. The questions could be related to the materials covered in the lectures on activated sludge or may surface a specific problem that a student has encountered in the field and which he would like to discuss in the hope that the instructor and class can provide him some guidance on how to deal with the problem.

Those questions and problems prepared by the students at the conclusion of the previous lectures should be reviewed and organized by the instructor before he begins this session. The questions should be answered in priority order as determined by the objectives of the activated sludge lesson. Those questions which support the objectives of the lesson should be answered first. If time permits, the other questions should be answered.

If the problem raised by a student relates to a specific plant and a problem that he has seen in the field, the instructor should request that the student assume the role of the operator and respond to questions that the instructor or class asks. Jointly the instructor and class should attempt to troubleshoot the situation and arrive at recommendations.

The instructor should not limit questions to those raised at the conslusion of the previous lecture, but should open the session to any other questions that the students might wish to ask.

ACTIVATED SLUDGE

LESSON PLAN – SUBDIVISION 5 **TIME: 45 Minutes**

Title: Troubleshooting – Hamsborough Treatment Plant

Instructor Objectives: To provide a realistic problem in the operation of activated sludge treatment plants for students to analyze and solve by applying the elements of the Process of Troubleshooting.

Student Objectives: As a result of the lesson subdivision, students will be able to do the following:

1. Visualize and describe all of the processes and facilities at a major activated sludge treatment plant
2. Analyze a normal plant operating situation
3. Determine location of sampling points, and data to be collected as part of a plant analyses
4. Review a plant situation undergoing considerable operating problems
5. Plan and execute the elements of the Process of Troubleshooting in solving activated sludge operating problems
6. List alternative solutions, and prioritize them in order of likely success
7. Identify means of upgrading plant performance to meet new, more stringent standards

Training Materials:

Slide Series of 20 Slides and Key

Problem Statement Part I and flow diagram, Student Notebook pages AS 20-22

Problem Statement, Part II, to be distributed by instructor

Answer Sheet, Student Notebook Page AS-23

Classroom Set-Up:

A normal classroom set-up will be required. Students *must* be seated with their student groups

35 mm carousel slide projector with remote controls

Large screen (8 ft x 10 ft)

Chalkboard or easel

Pointer

Subdivision Schedule:

Within the 45 minute time period, the following schedule should be followed:

TIME	SUBJECT
0 – 10 Minutes	Present the Hamsborough Situation
10 – 20 Minutes	Analyze Hamsborough
20 – 30 Minutes	Solve Part II
30 – 45 Minutes	Review Problem and Solutions, and Discussion

Subdivision Approach:

The basic approach to this subdivision is to present a realistic activated sludge operational problem, have the students analyze the problem, and have the class discuss it. The following steps should be followed:

1. Prior to the start of this subdivision, instructor should be sure that the students have pages AS 20-23 in their Student Notebooks. Part II of the problem must be reproduced in advance by the instructor for distribution
2. Instructor presents Part I of the problem, using Student Notebook pages AS 20-23
3. Instructor provides students with a "plant tour" of the Hamsborough Treatment Plant, by showing slides AS 5-1 thru AS 5-11
4. Students use the answer sheet, analyze Part I of the problem by working alone
5. Instructor distributes Part II of the problem. The instructor plays the role of "plant operator"
6. Students work in 4 person groups, answer the questions on Part II of the answer sheet
7. Student groups and instructor review and discuss the problem alternatives and solutions
8. Instructor shows slides AS 12-20 to demonstrate solutions to the Hamsborough problem

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
I. Present the Hamsborough Situation (10 Minutes)	
A. Part I of the problem, and a schematic flow diagram, is provided in the Student Notebook	Refer students to Student Notebook pages AS 20-23.
B. Discuss the problem statement	
1. Note that data shows nothing to be alarmed at	
2. Assume that this is the first visit that you are making to the plant and that it is a routine inspection	
3. Note your reaction as a tour is made through the plant simulated by the following slides	Have slide projector ready to go with set AS 5-1 through AS 5-20.
C. Plant tour	SLIDES
1. This shows a straight line rectangular primary clarifier. Note that digester supernatant returns to the head of the plant	AS 5-1
2. This is a roughing filter, a meat packing plant in the background used to discharge high strength wastes to the plant and this filter was used as a means of reducing the load	AS 5-2
3. The plant is an FMC rapid bloc plant. The aeration basin and clarifier have a common wall. Return sludge returns from the bottom of the clarifier to the aerator through a chimney with an air purge. You are told that this is done two or three times a day. Waste sludge is pumped through three air lift pumps; one is at the right of the operator. Note the black color in the final clarifier	AS 5-3
4. The cross section of the rapid bloc system is shown. Describe how the sludge return system works	AS 5-4
5. This shows an operator replacing socks on the diffuser	AS 5-5
6. This is a closer shot of the surface of the aeration basin	AS 5-6

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
7. Waste sludge is measured through a Parshall Flume. Air lifts operate three minutes every hour on a time clock basis and return sludge to the primary clarifier	AS 5-7
8. The settleometer reading is taken for control purposes. This is the settleometer at time 0	AS 5-8
9. Settling after five minutes	AS 5-9
10. Settling after thirty minutes	AS 5-10
11. Settling after sixty minutes	AS 5-11
II. Analyze Hamsborough (10 Minutes) Have the students turn to Student Notebook page AS-23. Students working alone should answer the four questions in Part I.	Guide: Students should work alone on Part I, in groups on Part II.
III. Solve Part II (10 Minutes)	Students should be seated with predetermined four-person groups.
A. Distribute one copy of the Problem Statement for Part II to each student	
B. The instructor plays the role of the operator and doesn't volunteer any information but does clarify questions asked by the trainee if the information is available to the instructor. The point should be stressed that the plant has a two-stage anaerobic digester with sand-drying beds. The plant has not drained digested sludge to the drying beds in over three months. Both digesters are full and every time the primary sludge is pumped to the digesters an equal volume of thick supernatant is returned to the primary clarifier. Odors, however, are minimal	
1. Students should work in groups of four and use the troubleshooting approach	
2. Student groups should answer the questions in Part II of the answer sheet	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
IV. Review of the Problem and the Solutions, and Discussion (15 Minutes)	
A. Note the following problems should have been identified by the class, listen to their response and then fill in any that are missing prior to going into the rest of the presentation	
1. Improper digester operation causing imbalance in the activated sludge system	Group question and answer.
2. Inability to measure and control return sludge rates	
3. Inability to effectively waste solids because of the digester problem	
4. An old inert activated sludge	
5. Excessive chlorine use	
6. Improper laboratory and reporting procedures	
B. Have the class recommend their solutions to these problems	Guide: Stress discussion between the student groups.
C. Solutions	
1. Note that the following solutions were actually attempted at the plant	
a. Empty and clean the digester	
b. Increase solids wasting	
c. Provide a sludge return system which was controllable	
d. Correct laboratory deficiencies	
e. The return sludge system recommended was an airlift system since this was least costly for the plant. The slides will illustrate the airlift system installation	
2. Show the solutions in the slide series	SLIDES
a. The aerator was drained and the RAS chimneys are shown on the left	AS-12
b. The chimneys were blocked, only one side of the plant was converted at first to be able to use the other side as control	AS-13

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
c. Airlifts were installed at a cost of approximately $2,400. Plant personnel did the work	AS-14
d. Airlift is shown installed in the hopper of the clarifier. The total depth is 18 feet. Later a T was added at the bottom	AS-15
e. This shows another view of the airlift. Note the air line on the side (perhaps a sketch of a typical airlift would be helpful here using a blackboard)	AS-16
f. Airlifts in operation. These were controllable between 30 and 70 gpm	AS-17
g. Airlift flow rate was measured by using a calibrated bucket and stopwatch. Later measuring flumes were added to the return sludge flow	AS-18
h. Sludge collected in the ends of the hoppers. A flange on the end of a rope was used to stir up the settled sludge in the ends of the hoppers. No significant plugging was encountered in the pump system	AS-19
i. Final effluent is shown here. After the total plant was converted to airlifts, the effluent ran 20/20 meeting and exceeding the NPDES requirements	AS-20

ACTIVATED SLUDGE – SUBDIVISION 5

Hamsborough Troubleshooting Problem – Part I

You, as newly appointed District Engineer for your State's Department of Environmental Protection, are preparing to inspect the Municipal Wastewater treatment plant at Hamsborough. As your first step, you search through your predecessor's files but can find only limited information on the facility; there has been no previous inspection of the Hamsborough facility. However, by digging further into the files you do find some information on the community and the plant.

Hamsborough is a small suburban community with a population of about 15,000 with some light industry, mostly trucking and warehousing operations. There are two significant industrial dischargers to the system, a small printing plant which specializes in novelty printing and a meat processing and packaging plant.

A schematic flow diagram of the Hamsborough Wastewater Plant is shown on page AS-22. The major plant units are: a primary clarifier, followed by a single stage high rate trickling filter, followed by a complete mixing activated sludge plant with final clarifiers, and a chlorination system for disinfecting the final effluent. Two anaerobic digesters are used in series to handle all the sludge removed from the treatment facilities.

The original treatment plant consisted only of the primary clarifier and a trickling filter. Due to high organic loads from the meat packing plant, the design hydraulic loading is 2.1 MGD but the design population equivalent is 45,000. In the last few years the packing plant has become mainly a meat processing operation and the wastes received from the plant carry much less organic material than was previously received. The meat processing plant has its own primary clarifier which removes some of the solids and grease before the sewage enters the treatment facility.

At the treatment site the primary treated meat packing wastes combine with the raw sewage from Hamsborough and then enter the primary treatment units. The primary clarifier is a rectangular tank approximately ninety feet long and forty feet wide. Primary sludge is scraped along the bottom of the tank to the head end where it is collected into a sludge hopper. Sludge is then pumped to the primary digester. Waste activated sludge, which includes trickling filter solids since there is no intermediate clarifier, also enters the primary clarifier and is pumped with the primary sludge to the primary digester. Supernatant from the digesters and from the drying beds is returned to the primary clarifier. Digested sludge is pumped out to the drying beds.

Effluent from the primary tank is pumped to a trickling filter. A portion of the trickling filter effluent is returned back to the wet well and is recycled through the filter. The flow pumped to the trickling filter is held at a constant rate by regulating the amount of filter effluent entering the wet well.

The trickling filter effluent not recirculated to the wet well enters the aeration system. There are essentially two identical activated sludge treatment units, and the flow is split between the east unit and the west unit. The aeration system is a package process which is essentially a high-rate complete mixing activated sludge rapid-bloc process. The aeration tank and final clarifiers have a common wall. Activated sludge enters the final clarifiers through ports between the clarifiers and aeration tanks. There are three airlift pumps for each unit to waste excess sludge. The settled activated sludge in the clarifiers is returned through a chimney type opening to the aeration basin. The driving force for the return sludge is primarily due to the upward lift action of the air diffusers in the adjacent aeration tanks — a principle much like that of an airlift pump.

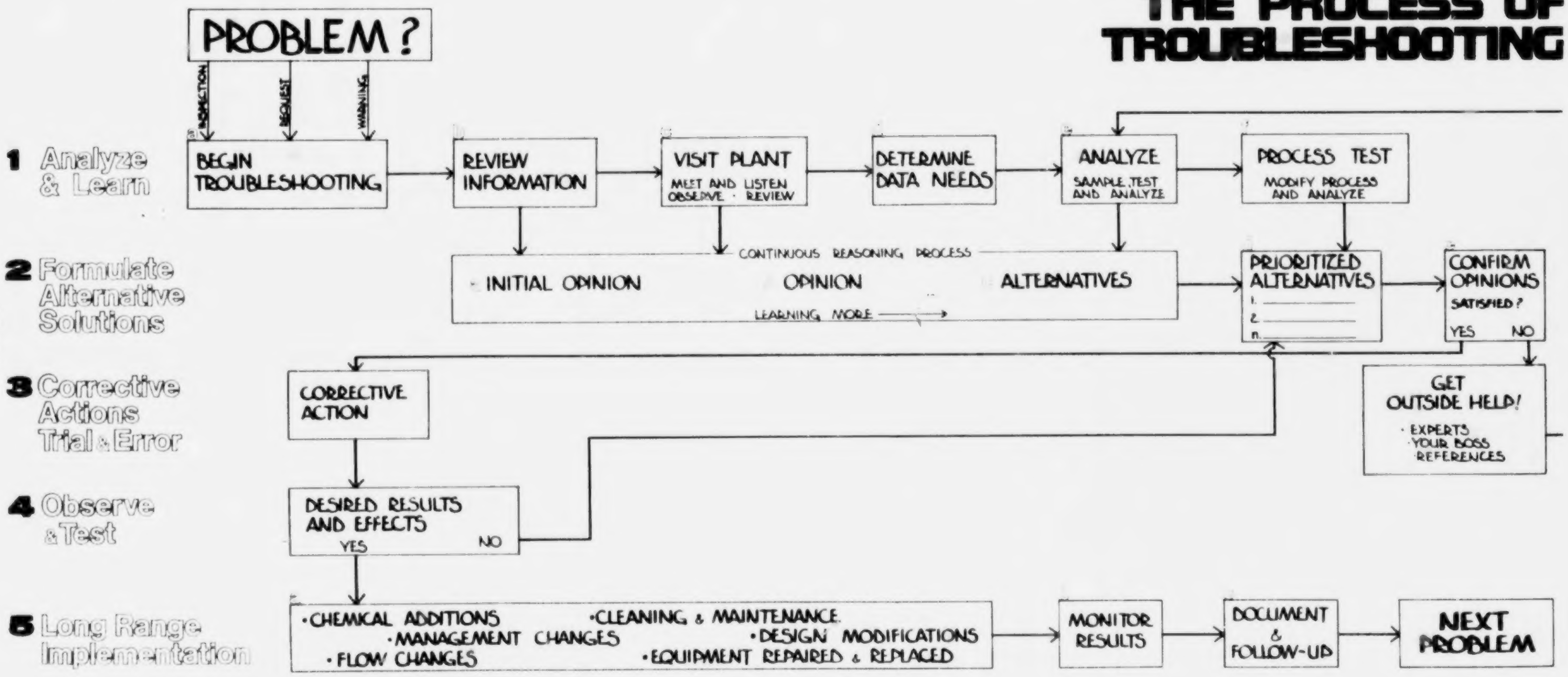
Clarified sewage passes over the weirs of the clarifiers to the effluent troughs and into a chlorine contact basin. The chlorine contact basin is a converted primary clarifier. Chlorine is introduced into the inlet pipe just prior to the introduction to the clarifier. The solids scraping mechanism of the clarifier is still intact. Disinfected sewage overflows the weirs, enters the discharge pipe and is discharged into Hamm Creek.

Performance data submitted to the state agency on monthly reports for the previous six months are summarized below:

Month	Flow, mgd			BOD_5	TSS	Cl_2
	Avg.	Max.	Min.	mg/l	mg/l	mg/l
September	2.12	2.55	1.83	–	13	0.4
October	2.14	2.52	1.84	14	19	0.5
December	1.59	1.87	1.23	8	18	0.5
January	1.80	2.25	1.30	7	20	0.5
February	1.70	1.83	1.52	7	14	0.5
March	1.63	1.74	1.48	12	19	0.5

Briefly review and answer the four questions that appear on the answer sheet in your Notebook under Part I.

THE PROCESS OF TROUBLESHOOTING


1 Analyze & Learn
2 Formulate Alternative Solutions
3 Corrective Actions Trial & Error
4 Observe & Test
5 Long Range Implementation
PROBLEM ?
INSPECTION
REQUEST
WARNING
BEGIN TROUBLESHOOTING
REVIEW INFORMATION
VISIT PLANT
MEET AND LISTEN
OBSERVE · REVIEW
DETERMINE DATA NEEDS
ANALYZE
SAMPLE, TEST AND ANALYZE
PROCESS TEST
MODIFY PROCESS AND ANALYZE
CONTINUOUS REASONING PROCESS
INITIAL OPINION
OPINION
ALTERNATIVES
LEARNING MORE
PRIORITIZED ALTERNATIVES
1.
2.
n.
CONFIRM OPINIONS
SATISFIED ?
YES
NO
GET OUTSIDE HELP!
· EXPERTS
· YOUR BOSS
· REFERENCES
CORRECTIVE ACTION
DESIRED RESULTS AND EFFECTS
YES
NO
· CHEMICAL ADDITIONS
· CLEANING & MAINTENANCE
· MANAGEMENT CHANGES
· DESIGN MODIFICATIONS
· FLOW CHANGES
· EQUIPMENT REPAIRED & REPLACED
MONITOR RESULTS
DOCUMENT & FOLLOW-UP
NEXT PROBLEM

(To be distributed by instructor)

ACTIVATED SLUDGE – SUBDIVISION 5

Hamsborough Troubleshooting Problem – Part II

During your inspection of the Hamsborough Treatment Plant you observe the following:

The primary clarifier contents look black and septic. When primary sludge was pumped to the digesters (a timeclock operation), it appeared that an equal volume of digester supernatant was returned to the primary clarifier. The supernatant return was deep black, shiny and appeared to have a very high solids content. The primary clarifier effluent was a dark, almost black color, and very turbid.

The stones on the trickling filter showed minimal growth. The filter effluent looked much like an influent.

Hydraulic loading to the aeration basins appeared to be equally split to the two sides of the system. There is no way to measure the actual flow to each basin.

The aeration basins are a dark brown. There is a thin layer of shiny, dark brown foam. The diffused air system appears to provide adequate mixing. During peak loads the DO in the aeration basin falls to values less than 1.0 mg/l. When this happens the operator turns on a third blower (two blowers are normally operated). With the third aerator DO can be maintained between 1.0 and 2.0 mg/l.

The final clarifiers have a considerable amount of septic sludge floating on top of them. The situation indicates that sludge is remaining on the bottom of the clarifiers in an anaerobic environment and may be going septic. Since the process relies on a lifting effect from the aeration system to pull sludge through a chimney from the bottom of the clarifier, it was suspected that the chimney was plugging. This was further supported by the fact that the operators routinely blew air through the chimneys in an effort to clean out blocked sludge. This disrupts the plant effluent for a period of time until all septic and nonsettling sludge was either washed over the weirs or finally settled again in the clarifiers. When black sludge was released from the bottom many small white worms were observed in the material.

A sample of the aeration basin mixed liquor was collected and a settleometer test run. The results of this test are summarized below.

ACTIVATED SLUDGE – SUBDIVISION 5

Hamsborough Troubleshooting Problem – Answer Sheet

Student Group ____________

Part I

1. Describe the steps you would take in approaching the inspection of the Hamsborough Plant.

2. Name the locations within the plant where you would have samples collected.

3. What data would you seek through sampling?

4. What are your preliminary judgments about the plant prior to your visit?

Part II

The instructor will assume the role of plant operator, and will answer any questions you may have.

5. Based on all of the observations made, indicate what your next steps would be in troubleshooting this plant. In proceeding through this portion of the exercise you are aware that the current NPDES permit for the facility requires an effluent which meets a 30 mg/l BOD and 30 mg/l TSS standard. In June, the State will revise the permit and the facility will be required to meet a 20/20 standard.

6. What actions will you take or recommend for this plant to meet the new, more stringent standard?

7. Which data would you collect and analyze before you make your final recommendation?

8. Prioritize alternatives and best solutions.

Time (Min)	Settled Sludge Volume (ml)
0	1,000
5	180
10	160
15	155
20	150
30	150
60	140

Visual observations made during the settling test included: very granular sludge leaving turbid supernatant, considerable quantity of "ash" floating on surface, unidentified white worms in settled sludge.

Final clarifier effluent turbidities were greater than 10 JTU. Return sludge samples could not be collected.

Waste sludge was removed from the final clarifiers by airlift pumps which run about 3 minutes per hour. Waste sludge flow is metered and then fed to the primary clarifier. Waste sludge flow averaged about 10,000 gpd. Centrifuge spins of waste sludge are in the range 13 – 18%. (Note that waste sludge is collected in hoppers in the final clarifiers and removed from the hoppers by the airlift pumps. Hence, the waste sludge may not be representative of the return sludge to the aeration basin.)

The old primary clarifier, which was converted for use as a chlorine contact basin, still has the scraper and sludge collection and removal mechanisms in place. These are frequently operated to remove solids from the chlorine contact basin. Effluent Cl_2 concentrations are about 0.5 mg/l. Detention time in the basin is about 2 hours. The final effluent is clear with low turbidity and has little or no color.

Composite samples of final effluent are collected automatically from the chlorine contact basin overflow weir channel. Effluent and suspended solids are run five times per week. While observing the test procedure you note that the BOD samples were not dechlorinated. In talking with the laboratory technician you also learn that he reports volatile suspended solids on the effluent quality report he submits to the State.

Inspection of the digesters shows that both digesters were filled to capacity. The sand drying beds were clean and do not appear to have been used for several months.

ACTIVATED SLUDGE

LESSON PLAN – SUBDIVISION 6 **TIME: 45 MINUTES**

Title: Troubleshooting – Pullman Treatment Plant

Instructor Objectives: To provide a troubleshooting problem in activated sludge for students to analyze and solve. To demonstrate the respiration rate control strategy as a means of controlling the activated sludge process.

Student Objectives: As a result of this lesson subdivision, students will be able to do the following:

1. Describe the conditions at an activated sludge treatment plant subject to extreme variations in loading
2. Analyze and troubleshoot process control problems at an activated sludge plant
3. Identify practical modifications in return activated sludge and in aerator mode system that may be implemented to control the activated sludge process
4. Describe the use of the constant respiration rate as a means of process control for activated sludge

Training Materials:

Student Notebook pages AS-24 through AS-36, including Answer Sheet, page AS-30

Classroom Set-Up:

A normal classroom set-up will be required. Students *must* be seated with their student groups

Chalkboard or easel

Pointer

Subdivision Schedule:

Within the 45 minute time period, the following schedule should be followed:

TIME	SUBJECT
0 – 10 Minutes	Description of Pullman Problem
10 – 25 Minutes	Student Analysis of Problem
25 – 40 Minutes	Solutions to Pullman Problem
40 – 45 Minutes	Questions and Discussion

Subdivision Approach:

The instructor is to provide the students with an opportunity to analyze and solve an activated sludge problem recently corrected through troubleshooting efforts.

All needed materials are in the Student Notebook

The basic approach is as follows:

Section I – The instructor uses Student Notebook materials to
present the problem to the class

Section II – Using answer sheet, student groups analyze the Pullman Problem

Section III – Groups report on their approaches to the Problem
Instructor uses notebook materials to present the approach actually used to successfully troubleshoot this problem

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
I. Description of the Problem and the Pullman Treatment Plant (10 Minutes)	Guide: Refer students to Notebook pages AS-24 thru 29.
A. Operational History 1. Have students read Notebook page AS-24 2. Answer questions on plant background and history	Refer to Student Notebook page AS-24.
B. Flow diagram – Have students briefly review 1. Page AS-25 – Complete Flow Diagram 2. Page AS-26 – Simplified Flow Diagram 3. Page AS-27 – Facts about the plant	Refer to Student Notebook pages AS-25, 26, 27.
C. Influent flow pattern 1. Have students review page AS-28 2. Describe causes for plant upset based on flow variations, as related to student activities High flows occur on days of: a. Rainy week days b. Home football games c. Snow melt 3. On an annual basis, the most difficult time is from September through January with vacations and highly variable weather	Refer to Student Notebook page AS-28.
D. Comparison of BOD removal 1. Note that in 1974, final effluent BOD averaged around 50 2. Troubleshooting assistance in October-November 1975 brought BOD levels below 30 ppm	Refer to Student Notebook page AS-29.
E. The problem for the students, and to be discussed by the instructor, is how the improvement was accomplished	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
II. Student Analysis of Pullman Problem (15 Minutes)	
A. Have students work in preselected student groups (4 persons)	
B. Have student groups use the answer sheet provided, page AS-30 to analyze the Pullman Problem	Refer to Notebook page AS-30.
III. Solutions to Pullman Problem (15 Minutes)	
A. Have student groups briefly present and discuss their approaches to the Pullman Problem	Guide: Class discussion of solutions should be stimulated.
B. Solution actually implemented – modified return activated sludge	
1. Installation of modified return activated sludge	Refer to Student Notebook page AS-31.
a. Note flow diagram, Notebook page AS-31	
b. Describe how the system was installed This was accomplished by attaching a 6-inch irrigation line onto the existing return sludge pipeline and extending it down the center of the two aeration tanks with valves installed on inlet points at three places into each aeration tank. Return sludge could then be introduced into the aeration tank at variable points in order to change the sludge characteristics	
2. Aerator Mode System	
a. Note diagram of aerator modes, page AS-32	Refer to Student Notebook page AS-32.
b. Describe the mode system. Designations were set up for the various modes of operation for transmitting information to operators on different shifts. Mode O was designated as that one where return sludge was fed at the head end of each aeration tank Mode No. 1 would be a situation where return sludge was fed to the second portion of one side and the head end of the other tank. Shaded areas designate the amount of the relative tank volume that was receiving returned sludge	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
D. Results – 1975	
1. Respiration Rate Control began in October, 1975. It took about a month for the system to adapt	
2. Results – November, 1975	Refer to Student Notebook page AS-34.
a. Final effluent BOD in 1975 is considerably below 1974 (avg 20 ppm less)	
b. BOD decreasing as control strategy takes effect	
3. Vacation and high flow periods	Refer to Student Notebook page AS-34.
a. Note fluctuations in flow, and primary BOD	
b. Note consistency in final BOD	
4. Final results – December 1975	Refer to Student Notebook page AS-36.
a. Note consistency of both RR and final BOD	
E. Credit for This Problem This troubleshooting problem was carried out at Pullman by Charles S. Zickefoose, Operation Consultant, Stevens, Thompson & Runyan, Inc., Portland, Oregon. Mr. Zickefoose also assisted in the preparation of these course materials	Guide: Instructor should cite the credit for this problem.
IV. Questions and Discussion (5 Minutes) Allow time for student questions and discussion on the Pullman case history	

LESSON OUTLINE

3. Sampling Schemes
    a. Note diagram, page AS-33
    b. Describe the sampling scheme. Samples were taken at the designated points shown with the major control point being that of No. 3, the mixed liquor respiration rate at the outlet of the aeration tank, and No. 8, the respiration rate of a mixture of return sludge and primary effluent

C. Control Strategy – Respiration rate

1. Eight to twenty milligrams O_2/gram MLSS/hour is apparently the optimum range
2. If the trend is toward a higher respiration rate, move toward a longer aeration time, and vice versa
3. Procedure used. A constant was determined for the combination of respiration rate of the primary effluent mixed with return sludge divided by return sludge rate. The optimum range was found by trial and error. Operators took a reading approximately three times a day and adjusted the return rate to maintain this constant
4. Respiration Rate Formula

$$K = \frac{RR\ (RAS + \text{Prim. Eff})\ Q}{\text{Conc. RAS} \cdot Q_R}$$

Where Q_R – Return Sludge Rate

Therefore, by finding the optimum constant, the operator can then adjust the return rate to continue good performance.

$$Q_R = \frac{RR\ (RAS + \text{Prim. Eff}) \cdot Q}{RAS \cdot K}$$

5. This is what was done at the Pullman Plant in 1975 to correct their operational problems

KEY POINTS & INSTRUCTOR GUIDE

Refer to Student Notebook page AS-33.

Guide: Instructor should note that the RR concept was presented in subdivision I. Students may refer to their notes.

Guide: Use chalkboard to briefly present this concept.

ACTIVATED SLUDGE

LESSON PLAN – SUBDIVISION 7 **TIME: 45 MINUTES**

Title: Activated Sludge Case Histories

Instructor Objectives: To present a series of six problems in activated sludge drawn from the experience of Mr. Al West, National Waste Treatment Center, EPA, Cincinnati. The problems presented relate to equipment defects and operational control procedures which were causing inadequate performance of the activated sludge system. Corrective actions which were instituted are illustrated to provide the students information on some techniques which can be used to overcome equipment related problems in treatment plants.

Student Objectives: As a result of this lesson subdivision, students will be able to do the following:

1. Analyze and solve hydraulic surging problems caused by improper manual control of raw sewage pumps
2. Identify a technique for correcting flow imbalance problems caused by unequal flows from a common channel
3. Identify procedures for correcting hydraulic imbalance caused by improper weir placement
4. Identify procedures for providing flexible return sludge flow control at small plants
5. Identify a cause for inadequate mixing for mechanically operated plants
6. Identify a blocked clarifier influent point that caused flow imbalance between multiple clarifiers

Training Materials:

Series of 26 slides illustrating activated sludge case history problems and solutions, and slide key

Classroom Set-Up:

A normal classroom set-up will be required. Students should be seated with their student groups

35 mm carousel slide projector with remote controls

Large screen (8 ft x 10 ft)

Chalkboard or easel

Pointer

Subdivision Schedule:

Within the 45 minute time period, the following schedule should be observed in presenting the lesson plan outline:

TIME	**PROBLEM**
0 - 5 Minutes	Hydraulic Surging
5 - 15 Minutes	Flow Imbalance
15 - 20 Minutes	Hydraulic Imbalance
20 - 25 Minutes	Return Sludge Flow Control at Small Plants
25 - 35 Minutes	Inadequate Mixing
35 - 40 Minutes	Blocked Clarifier Inlet
40 - 45 Minutes	Other Problems

Subdivision Approach:

The instructor should approach this subdivision by presenting problems to the class for discussion and joint solution. The prepared slides should be used to set up the problem with the instructor providing background information on the slide and then asking the class for their thoughts on how the problem might be resolved. After an appropriate time for discussion, the instructor should summarize and present the solution actually applied to the problem by troubleshooters in the field.

There are six problems in the lesson plan below. The time allotted for this segment may not be sufficient to discuss all of the problems and to present solutions. The problem statements as presented in the subject outline are in priority order based on relative frequency with which the troubleshooter may encounter the problem and the ease with which the troubleshooter can provide a solution. Some problems require rather extensive plant modifications and/or purchase of replacement parts in order to implement a solution. These problems are important but are given lower priority in the presentation.

The instructor may wish to augment the problems provided below with problems from his own experience providing that they are more relevant to the objectives of the lesson.

LESSON OUTLINE

I. Case History — Hydraulic Surging (5 Minutes)

   A. Plant Background

      1. Slide shows 24 hour influent flow

      2. 10 mgd activated sludge plant

      3. Raw sewage pumps are turned on and off manually.

         There are three pumps in the raw sewage lift station. Two are fixed speed pumps rated at 6 MGD. The others are variable speed with a maximum capacity of 6 MGD. The lift operators must drive to the station to turn on the pumps when they are needed. Night staffing at the plant is minimal, and the night operators do not go to the lift station to turn on the pumps or to control discharge rates from the variable speed pump

   B. Plant Problem

      This chart shows that there is a 7.5 MGD step in the influent flow rate each morning when the day shift activates the pumps. The second blip on the chart is caused by the variable speed pump being turned to a higher discharge rate. The step increase in influent flow causes hydraulic washout of the solids in the final clarifiers. As a result of the influent flow schedule, which is regular as clockwork day after day, the plant is operated to store solids in the aeration basins during the low flow periods so that added load of the step can be handled by the sludge. This practice contributes to the hydraulic washout problem as solids are moved from the aeration basin to the final clarifiers.

   C. Class analysis of Problem

   D. Actual Solution of Problem

      In the plant from which this case history is taken, the lift station is equipped with an automated flow controller, but it was never connected to the pumps and put into service

KEY POINTS & INSTRUCTOR GUIDE

Guide: Introduce the problem by showing Slide AS 7-1.

Guide: Instructor should encourage class discussion of the problem.

Guide: Instructor should present what really happened after the class has had an opportunity to discuss the problem.

LESSON OUTLINE	KEY POINTS INSTRUCTOR GUIDE
E. Plant improvement	Show Slide AS 7-2.
1. Slide shows the influent flow chart two days later after the automatic controller was placed in service. The flow smoothing which occurs eliminated the hydraulic washout of the final clarifiers. This required that the operators learn a new way to operate the process since the old mode of operation was no longer needed. Eventually the activated sludge process was balanced and overall plant efficiency increased appreciably.	
2. This slide permits a more ready comparison of the influent flow patterns before and after the automatic controller was placed in service.	Show Slide AS 7-3.
II. Case History — Flow Imbalance (10 Minutes)	Guide: Show Slide AS 7-4.
A. Plant Problem Slide shows obvious unequal flow from the two ports. Point out that there are other basins to the left which also have similar problems since all ports feed from the same channel. Point out that each port is fitted for a slide gate to block flow from that port.	
B. Class Analysis of Problem	Guide: Instructor should ask the students for recommendations on balancing flow thru the basins.
C. Actual Solution of Problem	
1. When the discharge ports are submerged with a six to eight inch discharge head, the flow could be balanced. Slide shows the installation of stainless steel machine bolts into the bottom side of the discharge port gate. The bolts were purchased at the local hardware store and a local machine shop tapped the gate for the bolts. The operator is shown here adjusting the height of one bolt using a micrometer gauge.	Slide AS 7-5.
2. Slide shows the gate being inserted into the port	Slide AS 7-6.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
3. Slide shows the balanced flow after all the gates had been adjusted to correct heights	Slide AS 7-7
4. Slide shows the entire plant looking from the effluent side of the final clarifier toward the aeration basins. Point out the gates installed at the head of the aeration basin to balance flow and the similar gates installed at the inlets to the final clarifier	Slide AS 7-8
5. Slide shows a closeup of the final clarifier ports with the gates in place. Point out the obvious velocity current as the mixed liquor enters the final clarifier. Inform the class that later the clarifiers were dewatered and target plates installed to correct this problem	Slide AS 7-9
III. Case History – Hydraulic Imbalance (5 Minutes)	
A. Plant Problem Point out the excessive weir length in the corners of the basin caused by the inclusion of both corner and diagonal weirs	Guide: Show Slide AS 7-10.
B. Class Analysis of Problem	Guide: Ask the class what they think would happen in this clarifier.
1. Confirm that the extra weir length in the corners does indeed cause a direct short-circuiting and excessive flow to the corners washing solids over the weirs at the corners	
2. Point out the simple correction shown in the lower left hand corner. Block off the weirs that are causing the problem	
C. Effect of Weir Problem Slide shows billowing sludge in the anular space between the outermost weir and the wall of the clarifier. Note to the class that sludge quality is good and that the sludge settles well	Slide AS 7-11
D. Actual Solution of the Problem	
Slide shows that the problem was solved by blocking off both the outermost and outer anular weir to eliminate the hydraulic washout of sludge caused by the velocity currents at the wall	Slide AS 7-12

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
IV. Case History – Return Sludge Flow Control at Small Plants (5 Minutes)	
A. Plant Problem	Slide AS 7-13
The operator of this plant was asked to modify the return sludge flow rate, stated that he could only change it about 15% and didn't want to do so because it would be difficult. When asked to show how he changed return flow rate, he demonstrated the following:	
1. He went to the shop and got most of his tool chest 2. He went to the return sludge pump and removed the pump housing 3. Loosened the impeller shaft retaining nut	
4. Took his hammer and banged down the pump impeller shaft	Slide AS 7-14
5. Went to the control panel to check to see if the flow was correct 6. Repeated 4 and 5 until the correct flow was obtained 7. Reassembled the pump and waited for the next requirement to change return flow	
Any question why this operator didn't adjust his return flow to satisfy process demands? Note that this is a small plant with flows of about 0.5 MGD	
B. Class Analysis	Guide: Have class discuss then recommend solutions to this problem.
C. Actual Solution of Problem	
Because the plant is small, portable pumps can be used as an interim measure while the uncontrollable return pump is being replaced	Slide AS 7-15
V. Case History – Inadequate Mixing (10 Minutes)	
A. Plant Problem	
1. Show slide pointing out the dead spots between aerators. State that in the plant the MLSS was very low and the plant was never able to develop sludge	Slide AS 7-16

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
2. The bottle on the left is a settled sample of the bottom sludge from aerator Bay No. 1. The bottle on the right is a sample taken from the bottom of the aerator Bay No. 2. The bottom sludge was 40,000 mg/l in Bay 1 and 15,000 mg/l in Bay 2	Slide AS 7-17
B. Class Analysis	Guide: Ask the class to identify the problem and its probable cause.
C. Actual Problem and Causes The problem is inadequate mixing in the aeration basin which permits the solids to settle out in the aeration basins rather than being held in suspension. Possible causes include undersized mechanical aerators, too few mechanical aerators, inadequate draft tubes on the mechanical aerators, etc	
D. Attempted Troubleshooting of Problem	
1. This slide shows one of the aerators being lifted from the tank	Slide AS 7-18
2. Slide shows the draft tube on the aerator. Note that this is about an 18 inch draft tube on an aerator in a 20 foot deep aeration tank. Anyone question why mixing was inadequate?	Slide AS 7-19
3. Slide shows the operators replacing the draft tubes with an eight foot draft tube set which was at the plant site. Note that the construction grant on this project had not been closed out and corrections were still being made	Slide AS 7-20
4. Slide shows the aerator with the longer draft tube being returned to service	Slide AS 7-21
5. Slide shows the black septic sludge from the tank bottom being disturbed as the new aerator was first put into service. But alas, the problem still persists because the draft tubes don't reach far enough into the tank as shown on the next slide. Within a few hours things had settled out again and no noticeable improvement was achieved	Slide AS 7-22 AS 7-23

LESSON OUTLINE

E. Epilogue – Ode to the Troubleshooter!

The troubleshooter in this case called this problem to the attention of the City Engineer forcefully. He in turn has demanded that the consulting engineer and aerator manufacturer correct the inadequacy. Ah! The beauty of catching problems early

VI. Case History – Blocked Clarifier Inlet (5 Minutes)

A. Plant Background

A plant had been in operation for more than eight years and had always been plagued with unequal flows to the two final clarifiers

B. Class Analysis of the problem

Some of the causes which might be identified include:

1. Overflow weirs out of level
2. Improper hydraulics in inlet channels
3. Line blockages on inlet side of the clarifiers

C. Troublehsooting the Problem

The obvious causes were checked immediately. By transit it was determined that the effluent weirs were level and at the same elevation. Inlet channel hydraulics were checked out and no discernible problems were found. The troubleshooter recommended that the clarifier receiving low flow be dewatered and thoroughly inspected. This was done as shown in the slide. During the inspection a 4 x 8 foot piece of plywood which the contractor had left in the inlet structure of the clarifier was found

D. Epilogue

It's hard to believe that his problem had persisted for eight years and that no one had found the cause. A good pre-start-up inspection and a thorough, planned start-up procedure should have surfaced this problem and solved it long before the troubleshooter was ever called in

KEY POINTS & INSTRUCTOR GUIDE

Key Point: Quick troubleshooting assistance can be invaluable.

Guide: Ask class to identify possible causes of the flow imbalance.

Slide As 7-24
Slide AS 7-25
Slide AS 7-26

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

VII. Other Case History Problems (5 Minutes)

A. Ask the class to identify any other problems that they have seen and would like to present to the class for discussion

B. If time is remaining, the instructor may introduce any case history problems with which he is familiar, that may be of interest to the class

ACTIVATED SLUDGE

LESSON PLAN – SUBDIVISION 8 **TIME: 45 MINUTES**

Title: Small (Package) Activated Sludge Plants

Instructor Objectives: To provide a general understanding of the composition and operations of package treatment plants and how to troubleshoot problems at package plants.

Student Objectives: As a result of this lesson subdivision, students will be able to do the following:

1. Describe various configurations of package plants
2. Identify common package plant features
3. Describe components of package treatment plants
4. List and carry out normal process control observations used in operating and maintaining package plants
5. Describe the expected performance of extended aeration and contact stabilization plants
6. Use the Process of Troubleshooting to correct operational problems at package plants
7. Identify and correct common operating problems in package treatment plants

Training Materials:

"Extended Aeration-Training Course MTM-01," Water Pollution Control Federation, Washington, D.C., including the following materials:

- Audio Tape Cassette 1 – Part 1, "Routine Operations, Procedures, and Select Maintenance Considerations," minutes 4-13 on tape
- Slides selected from MTM-01 Course as follows:
  Slides 5-15, 21-23, 26, 32-34, 36, 39, 41-44, 48-50 (Slides provided with materials for this course)
- Course text of slides

Flow diagram for package plants, Student Notebook pages AS-42 thru As-46

Studies of Extended Aeration Plants, Student Notebook page AS-37

Tables on Contact Stabilization Performance, Student Notebook Pages AS-38 & AS-39

Troubleshooting Guide, Student Notebook Page As-40

Checklist for Small Package Plants, Student Notebook Page As-41

Supplemental Information: The title page and text of Slides 1-51 of the WPCF Course are provided for the instructor's information

Classroom Set-Up:

A normal classroom set-up will be required

Students should be seated with their student groups

35 mm carousel slide projector with remote controls

Large screen (8 ft x 10 ft)

Chalkboard or easel

Pointer

Subdivision Schedule:

Within the 45 minute time period, the following schedule should be observed in presenting the lesson plan outline

TIME	SUBJECT
0 – 5 Minutes	Introduction
5 – 25 Minutes	Common Plant Features, Operation and Control
25 – 30 Minutes	Plant Performance
30 – 40 Minutes	Troubleshooting Package Plants
40 – 45 Minutes	Summary and Questions

Subdivision Approach:

This subdivision is designed to be presented using visual aids (slides and notebook diagrams) to illustrate package plant configurations, problems, and recommended solutions. The instructor should be prepared to discuss specific points with the class and respond to questions. The instructor should capitalize as much as possible on the experience and expertise of the students for these discussions.

It would be useful for the instructor to become familiar with the WPCF training module on extended aeration. All of the slides in that module (105) are accompanied by audio tape cassettes. We have selected 27 of those slides for use in this course, and are recommending that some be accompanied by the tape (Tape 1 – Minutes 4-13) and others by the narration of the instructor. However, the instructor, if he is familiar with the WPCF materials, may vary the approach to suit his needs.

Sections III and IV of the lesson plan make heavy use of Student Notebook materials. The instructor should make sure that all of these materials have been distributed to the students.

The instructor should emphasize class discussion of problems they have seen and experienced.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
I. Introduction to Package Plants (5 Minutes)	
A. Definition	
1. Self-contained plants that can be transported to a site in essentially a ready-to-go state, and handle flows of approximately 50,000 gpd	Guide: Call on class for other descriptions or definitions of package plants.
2. The plants being considered here are at least large enough to require an NPDES permit, as opposed to units that serve individual dwellings and other specialized users	
3. One man or less is required to operate the facility	
B. Comparison of various configurations of package plants	Guide: Refer students to Notebook pages AS-42 thru AS-46 for these diagrams.
1. Circular: This is a contact stabilization pattern. The instructor should refer back to Subdivision I which describes this basic treatment system	Notebook Page AS-42
2. Circular configuration with tertiary treatment. Explain the various components in sequence and trace out flow patterns	Notebook Page AS-43
3. An alternative circular configuration	Notebook Page AS-44
4. Some rectangular plants have a moving suction system for return sludge. This diagram shows the details of such a system	Notebook Page AS-45
5. Oxigester rectangular plant with fixed return sludge airlift pump. Trace out the general flow pattern of this plant and discuss its features	Notebook Page AS-46
II. Common Plant Features, Operation and Control (20 Minutes)	
A. Plant features (slides from WPCF Extended Aeration Course – Narration on Tape)	Note: Use tape from Minute 4 (slide 5) thru minute 13 (slide 15). Text of tape is available as a supplement to this lesson plan.

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

Slide Subject	Slide No. WPCF Designation	Slide (as numbered in sequence for this course)
1. Typical configuration	5	AS 8-1
2. Inlet structure	6	AS 8-2
3. Aeration tank – MLSS	7	AS 8-3
4. Clarifier with sludge blanket	8	AS 8-4
5. Clarifier with RAS	9	AS 8-5
6. Aerator with air and RAS	10	AS 8-6
7. Importance of aeration-clarifier system	11	AS 8-7
8. Plant effluent	12	AS 8-8
9. Holding tank/aerobic digester	13	AS 8-9
10. Support equipment and lab	14	AS 8-10
11. Complete plant layout	15	AS 8-11

B. Components of Package Plants

Guide: Instructor should comment briefly on each slide, seek class input.

	SLIDE	
	Course No.	WPCF No.
1. The slide depicts air and mixing system		
a. Note problems of common piping to diffusers and airlifts hard to balance	AS 8-12	21
b. Over aeration is a problem. Need time-clock to control dissolved oxygen		
2. Slide shows two kinds of headers:	AS 8-13	22
a. Need to be checked for rags. Fixed type are hard to handle for one person		
3. Detail of an airlift pump	AS 8-14	23
a. This is a simple pump but sometimes hard to regulate		
b. Cap outlet end and turn air on to back-flush, or close the airline and use water pressure		
c. Why is it necessary to close the airline? (To prevent forcing water backup into the blower)	Guide: Question students on this point.	
4. Skimmer: This is the same principle as the airlift pump	AS 8-15	26
5. Chlorination system: Many times this may be HTH, particularly if the plant is small	AS 8-16	32

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE	
6. Flow measurement: Need to show an operator how to read a V-Notch weir to check meter accuracy	AS 8-17	33
7. Example of reading a chart for a V-Notch weir	AS 8-18	34
8. Example of a flow chart	AS 8-19	36
9. Wasting is an important control step. May have to help the operator locate someone to hold sludge	AS 8-20	39
a. 70% settleable solids is a rough indication of when it is necessary to haul sludge	Key Point: Solids wasting, or lack of, often is the principal factor in plant performance.	
b. Loss of solids when 25-30% settleability exists may mean hydraulic upsets due to too much skimming water or infiltration	SLIDE	
C. Process Control Observations	Course No.	WPCP No.
1. Odor and visual indicators	AS 8-21	41
2. Normal conditions described	AS 8-22	42
3. Yellow or local soil color may indicate a contractor digging in the system letting in dirt. Have the class comment	AS 8-23	43
4. Septic conditions	AS 8-24	44
a. Flat sewers and low flow		
b. Not enough air		
c. Sludge allowed to set too long		
5. Insufficient air	AS 8-25	48
a. Aerator black		
b. Rising black sludge on the clarifier		
6. Over-aeration	AS 8-26	49
a. Sludge has a red color		
b. Floc "beat up"		
c. High DO		
d. Sludge turbid in settling test		
e. Install timeclock on the system to control air feeding		

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

SLIDE

Course No.	WPCP No.
AS 8-27	50

7. Improper airlift operation
    a. Sludge rising in clarifier
    b. Solids low in aeration tank
    c. Blanket high in the clarifier

III. Plant Performance (5 Minutes)

A. Troubleshooters should be aware of the expected performance of package extended aeration and contact stabilization plants

B. Extended Aeration Plants

1. Have students briefly review the table on page AS-37

Refer students to Student Notebook page AS-37. Studies of 4 extended aeration plants.

2. Note removal rates and loading ratios

3. Note that this information originates from a report done by the National Sanitation Foundation characterizing experimental results derived from comparisons of 4 extended aeration package plants using a flow pattern that might be found in a subdivision

C. Contact Stabilization Plants

1. Have students review the tables on pages As-38 and AS-39

Refer students to Student Notebook pages AS-38 & AS-39.

2. Note the differences in solids carried between the Winter-Spring and Spring-Summer situations

Guide: Encourage class to discuss these results. and to account for the differences in performance.

3. Note that this information was derived from a comparison of a number of contact stabilization package plants using a variable flow pattern and testing was done during different parts of the year

IV. Troubleshooting Package Plants (10 Minutes)

Note: This section relies heavily on Student Notebook materials.

A. Troubleshooting based upon observations and trouble indicators

1. Note the following troubleshooting steps from the chart

Refer to Process of Troubleshooting Chart – Student Notebook.

SPRING AND SUMMER STUDIES
FOUR EXTENDED AERATION PACKAGE SEWAGE TREATMENT PLANTS
SUBDIVISION FLOW PATTERN

(mean values)

ITEM	INFLUENT	EFFLUENT FULL LOAD	 HALF LOAD
1. BOD$_5$ (mg/l)	198	20	10
2. SS (mg/l)	234	36	32
3. VS (mg/l)	192	26	22
4. COD (mg/l)	220	32	18
5. % Volatile	82	72	69
6. pH	7.8	7.1	7.2
7. Alkalinity (mg/l)	48.0	19.8	14.2
8. NH$_3$–N (mg/l)	17.4	0	0
9. NO$_3$–N (mg/l)		15.3	20.0
10. PO$_4$–P (Total Soluble) (mg/l)	11.3	11.3	10.3
11. Dissolved Oxygen (mg/l)		1.6	2.2
12. M.B.A.S. (mg/l)	6.1	0.8	0.9
13. BOD/SS	0.85	0.56	0.31
14. BOD/VS	1.03	0.77	0.45
15. BOD/COD	0.90	0.63	0.56
16. % Reduction			
a. BOD$_5$		90	95
b. SS		85	86
c. VS		86	89
d. COD		85	92
e. Alkalinity		59	71
f. NH$_3$–N		100	100
g. PO$_4$–P		0	8.8
h. M.B.A.S		87	85

	Mixed Liquor Full Load	 Half Load
17. MLSS (mg/l)	4,330	3,050
18. MLVSS (mg/l)	3,120	2,130
19. % Volatile	72	70
20. pH	7.3	6.9
21. SV$_{30}$ (ml)	650	285
22. Sludge Density Index	0.67	1.07
23. Temperature (°C)	18.6	18.2
24. Dissolved Oxygen (mg/l)	2.0	3.0
25. lb BOD$_5$/lb MLSS	0.05	0.03
26. lb BOD$_5$/lb MLVSS	0.06	0.05

WINTER AND SPRING STUDIES
CONTACT STABILIZATION PACKAGE SEWAGE TREATMENT PLANTS
FULL DESIGN LOADING — VARIABLE FLOW PATTERN

	INFLUENT				EFFLUENT				
Item	No. of Samples	Min.	Max.	Mean	No. of Samples	Min.	Max.	Mean	Percent Removal
BOD$_5$	248	112	305	184	236	6.0	236	46	75.0
SS (mg/l)	252	98	282	171	251	0.0	238	24	86.0
VSS (mg/l)	248	88	234	145	248	0.0	198	19	86.9
COD (mg/l)	244	164	652	368	241	20	272	74	79.9
NH$_3$-N (mg/l)	124	10.0	25.0	18.5	124	1.0	20	10.6	
NH$_3$-N (mg/l)	128			***	128	0.2	20.2	4.5	
PO$_4$-P (mg/l)	120	22.0	72.0	37.2	120	12	40.8	26.5	28.8

MIXED LIQUOR AND STABILIZATION COMPARTMENT SOLIDS

Item	No. of Samples	Min.	Max.	Mean	Percent Volatile
MLSS (mg/l)	252	660	5,260	1,942	79.9
MLVSS (mg/l)	249	420	4,530	1,552	
SV$_{30}$ (ml)	248	50	850	343	
SVI	248	41	495	177	
SCSS (mg/l)	246	600	8,010	2,924	80.4**
SCVSS (mg/l)	125	850	6,640	2,492	
RSS (mg/l)	540	1,000	8,400	3,485	81.6**
RSVSS (mg/l)	43	1,170	6,400	3,332	

* These data were collected during the period of criteria development and are not the result of testing under the conditions established for certification testing.

** Calculated from paired samples only.

*** The mean NO$_3$-N in the influent for this series of data was 0.2 mg/l.

SPRING AND SUMMER STUDIES
CONTACT STABILIZATION PACKAGE SEWAGE TREATMENT PLANTS
FULL DESIGN LOADING – VARIABLE FLOW PATTERN

	INFLUENT				EFFLUENT				
Item	No. of Samples	Min.	Max.	Mean	No. of Samples	Min.	Max.	Mean	Percent Removal
BOD_5	87	100	297	167	86	1.0	220	37	77.8
SS (mg/l)	88	126	344	184	88	3.0	318	45	75.5
VSS (mg/l)	88	70	278	149	88	0.0	218	35	76.5
MBAS (mg/l)	83	1.9	10	5.6	83	0.0	2.4	0.6	89.3
COD (mg/l)	88	140	676	368	88	16	392	89	75.8
NH_3-N (mg/l)	88	6.0	22.1	17.1	88	3.3	22.1	10.7	
NO_3-N (mg/l)	88			**	88	0.3	16.0	3.5	
PO_4-P (mg/l)	87	21	80	52.9	87	23.2	53.6	36.3	31.4

MIXED LIQUOR AND STABILIZATION COMPARTMENT SOLIDS

Item	No. of Samples	Min.	Max.	Mean	Percent Volatile
MLSS (mg/l)	91	1,300	6,650	3,406	75.2
MLVSS (mg/l)	91	970	4,550	2,561	
SV_{30} (ml)	91	90	950	531	
SVI	91	39	486	156	
SCSS (mg/l)	68	2,970	8,460	5,572	76.5
SCVSS (mg/l)	68	2,270	6,840	4,264	
RSSS (mg/l)	91	1,110	11,580	6,935	73.0
RSVSS (mg/l)	91	740	8,830	5,062	

*These data were collected during the period of criteria development and are not the result of testing under the conditions established for certification testing.

**The mean NO_3-N in the influent for this series of data was 0.4 mg/l.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
a. Step 1C, Observe and review b. Step 13, Sample, test and analyze c. Note that these steps are particularly valuable in troubleshooting package plants	
B. Review troubleshooting guide briefly for each of the six cases on the guide, as follows	Refer to Troubleshooting Guide – Extended Aeration Plants, Student Notebook page AS-40.
1. Case I – Normal Sludge 2. Case II – Hydraulic Overload 3. Case III – Need for Wasting 4. Case IV – Denitrification 5. Case V – Industrial Waste 6. Case VI – Under-aeration	Guide: For each case, have class discuss the interpretation, Column 3, and the action required, Column 5.
C. Other Problems 1. Problems with scum 2. Foaming 3. Rags 4. Other	Guide: Seek class discussion on other problems they may have encountered.
D. Package Plant Checklist 1. Designed for routine maintenance 2. Useful for troubleshooting	Refer class to Student Notebook page AS-41.
V. Summary and Questions (5 Minutes)	

TROUBLESHOOTING GUIDE – EXTENDED AERATION PLANTS

CASE NO.	AERATION TANK SAMPLE JAR CONDITIONS	PLANT EFFLUENT SAMPLE JAR CONDITIONS	INTERPRETATION	CONFIRMATORY PLANT CONDITION OBSERVATIONS	ACTION REQUIRED
I	Heavy, rapid settling, brown sludge occupying 10 - 70% of the jar volume. Clear liquid above sludge. Faint musty, earthy odor.	Light dusting of fine pinpoint solids on bottom. Clear liquid above. Faint musty odor.	Plant in good operating condition.	No objectionable odors. Clear effluent. No black or born sludge floating on surface of settling tank.	None
II	Same as Case I.	Relatively large volume of sludge on bottom of jar – 1/8" or more thick. Faint musty odor.	Excessive loss of solids because of too high a flow rate through settling basin.	Flow into plant abnormally high. Indicated by measuring weir or depth of flow in inlet or outlet sewer.	Check sewer system for storm water infiltration or unusual water discharges. If lift station precedes plant, reduce discharge rate.
III	Very heavy but good settling brown sludge occupying 70% of jar volume or more. Unobjectionable musty odor.	Very large volume of brown sludge on bottom of jar. Musty odor.	Excessive loss of solids because of too high a solids concentration in aeration tank.	Heavy solids concentration in settling basin for entire depth and solids discharging over effluent trough weirs.	Remove solids from system by pumping to tank truck and hauling to farm land or dump.
IV	Poor separation of solids from liquid. Little clear liquid. Brown fluffy sludge hangs in liquid or floats on water surface. Faint musty, earthy odor.	Relatively little settling of solids. Fluffy solids in suspension in liquid and floating at surface. Faint musty odor. Little clear liquid.	Denitrification in settling basin releases nitrogen gas causing sludge to float.	No objectionable odor in aeration tank. Blanket of brown sludge over surface of settling basin which will gradually turn septic if not removed.	Reduce air supply. Increase rate of returning sludge to aeration tank if possible to reduce settling basin retention time.
V	Heavy, rapid settling, darb brown or dark gray to black sludge occupying 15 - 70% of jar volume. Cloudy or turbid liquid above sludge. Musty or faint septic (sour) sewage odor.	Relatively more solids than in Case I. Bottom of jar covered with distinct layer of sludge. Liquid cloudy to turbid. Noticeably septic odor.	Deficiency in animal predators (protozoa) to feed on bacteria, probably caused by too little air but possibly by abnormal pH (acidity or alkalinity), if septic conditions are not present.	Aeration tank contents abnormally dark with possible septic odor. Cloudy effluent with possible septic odor.	Increase air supply. Check pH if septic conditions are not present. Add lime or soda ash if pH is below 6.0. Add acid if pH is above 9.0. Check for industrial wastes. Eliminate if found.
VI	Very heavy, fair settling, dark gray or black sludge occupying 50% of jar volume or more. Septic odor.	Same as Case III, except sludge is dark gray or black instead of brown.	Too little air for heavy solids load and excessive loss of solids in plant effluent because of too high a solids load in aeration tank.	Same as Case III except solids are dark gray or black instead of brown.	Increase air supply if possible and waste solids as in Case II. Check for overload and add treatment capacity if needed.

SMALL PACKAGE PLANT DAILY CHECKLIST*

1. Clean bar screen and pick up sample for raw settleable solids test
2. Notice conditions of floc
3. Notice conditions of aeration chamber
4. Notice conditions of sludge return
5. Check for foam on aeration chamber
6. Final Clarifier:
   a. Check surface skimmer
   b. Check appearance of clarifier liquid
   c. Clean weir troughs
   d. Squeegee solids
   e. Check level of sludge blanket
   f. Remove any leaves, etc from surface
   g. Pick up sample for final effluent settleable solids test
   h. Check chlorine residual
7. Air Compressors:
   a. Visually inspect motors
   b. Listen for any unusual noises
   c. Rotate motors and change compressors
   d. Inspect motors for overheating
   e. Check oil levels
   f. Grease motors if needed
      (Motors should be greased as specified by the manufacturers. normally, when manufacturing information is not available, two small shots of grease every 6 months is sufficient)
   g. Inspect Hypochlorinator:
      1. Determine HTH level
      2. Check discharge line

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* Provided by the Texas Water Quality Board

Supplemental Information for Instructor

PROCESS CONTROL, EXTENDED AERATION
WASTEWATER TREATMENT PLANTS

WPCF – MANFORCE Training Module–01
(with Audio-Visual Aids)

DDS-MTM-01
MODERATOR'S WORKBOOK

Prepared by
Water Pollution Control
Federation–Manforce

Technical Support and Review by
WPCF, Personnel Advancement Committee
Sam L. Warrington, Chairman

Special Training Techniques by
Data-Design Laboratories
Cucamonga, California 91730

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GRANT PROJECT PERSONNEL

G.W. Burke Jr., Director
J.A. Voegtle, Assistant Director

MTM-01 MODERATORS WORKBOOK

AUDIO SCRIPT

CASSETTE 1 – PART 1, ROUTINE OPERATIONS PROCEDURES AND SELECT MAINTENANCE CONSIDERATIONS

(Tone – Slide 1) This wastewater treatment presentation was produced for the Water Pollution Control Federation MANFORCE program by Data-Design Laboratories. It is oriented toward operators of extended aeration treatment plants with maximum capacities of approximately 50,000 gallons per day. The program is in three parts with each part presented on a cassette: Part 1 – Routine Operations and Procedures and Select Maintenance Considerations; Part 2 – Process Control; and Part 3 – Safety.

(Tone – Slide 2) Part 1 presents basic plant design, functions of various areas of an extended aeration plant, and select maintenance requirements.

You will notice in this presentation that the term wastewater is used instead of the term sewage. Actually the two terms have the same meaning. There is nothing improper about use of the term sewage but in recent years wastewater has been adopted in its place. This has minimized confusion with the term sewerage, and its improper use. The term sewerage is not simply wastewater but the entire wastewater system – the collection sewers, pumping and treatment facilities, and the solids and liquid disposal facilities.

Scientific studies conducted during the last decade have confirmed the value of the extended aeration treatment process. *(Tone – Slide 3)* This method of wastewater treatment is based on the principle that if activated sludge is retained in the system rather than wasted, its concentration will rise to a given quantity and then the rate of increase tends to level off. Since its conception, the process has been successfully employed in large treatment facilities like the one shown. *(Tone – Slide 4)* The same process is also used in smaller package plants like this one. Both operate on the same principle of retaining activated sludge. The name "extended aeration" is derived from the fact that the aeration period used in this process is longer than in other types of activated sludge wastewater treatment plants. Both large plants and small package plants operate in a similar manner. The subject matter of this training program is confined to small package plants.

In this picture a steel prefabricated plant is buried in the ground. Construction has recently been completed and the aeration tank has not yet been filled to its normal operating level. Prefabricated units such as this may also be installed above ground.

(Tone – Slide 5) This is a pictorial representation of an extended aeration plant. Each of the major operating areas of the facility is shown. To gain a better understanding of the process, its operation, and control, each area will be examined separately.

(Tone – Slide 6) The raw wastewater that enters the plant is known as the plant influent. It first passes through either a comminutor or a bar screen. The comminutor is a machine which cuts up and shreds the large solids normally present in the plant influent. This prevents the large solids from entering the plant and clogging airlift pumps or other piping

The bar screen may be used alone in the absence of a comminutor to remove sticks, rags, paper, and other objects from the influent to prevent these items from entering the plant. As shown here, a bypass bar screen is often used in conjunction with a comminutor to provide for the removal of coarse solids at times when the comminutor may be out of service.

(Tone – Slide 7) The first treatment unit that the raw wastewater enters is the aeration tank. Here air is pumped into the tank contents by means of a low pressure compressor commonly termed a blower. The air serves two functions. It mixes the tank's contents and it provides the oxygen which is essential to the proper operation of the process.

Some of the microorganisms normally present in wastewater can, if oxygen is available, use the organic pollutants from the wastewater as food. This results in the growth and reproduction of these organisms. Ultimately a visible, biologically active solid is produced. This is an activated sludge particle. Mixing the tank's contents by blowing air into it prevents these particles from settling. It keeps them suspended. In this way they are not only supplied with the oxygen they need but they are able to come in contact with the organic food they require for their continued growth. The oxygen used by these organisms is that which is transferred from the air bubbles to the liquid. This is known as dissolved oxygen.

(Tone – Slide 8) After aeration for a period of 16 – 24 hours, the wastewater flows to the settling tank. Here there is no mixing action. The tank is quiet and the activated sludge particles, which are normally heavier than water, begin to settle. They tend to clump together and form larger particles that are known as "floc." Because the sludge particles have grown by using the organic matter in the wastewater, their settling represents a separation of the pollutants from the wastewater. The liquid near the surface of the settling tank is, therefore, much clearer than the raw wastewater.

The activated sludge flocs concentrate in the bottom portion of the tank to form what is known as a "sludge blanket." The clearer liquid on top may be referred to as "supernatant."

(Tone – Slide 9) The settled sludge must be removed from the settling tank or its depth would increase to the point where it would flow out of the tank. If this happened there would be very few pollutants removed by this process.

An airlift pump is most often employed to remove the sludge and return it to the aeration tank. This is known as return activated sludge. When it is returned to the aeration tank it serves as "seed" material for the development of more activated sludge particles. The return of sludge is important both to maintaining the sludge blanket at a proper depth in the settling tank and to the growth of sludge in the aeration tank. Remember that as this sludge grows and is settled it removes pollutants from the wastewater.

(Tone – Slide 10) The return activated sludge is brought back to the inlet end of the aeration tank. It sometimes is introduced into the raw wastewater before it enters the aeration tank. It sometimes is introduced into the raw wastewater before it enters the aeration tank. The mixture of wastewater and return activated sludge is known as a mixed liquor. The content of the aeration tank is known as the mixed liquor.

(Tone – Slide 11) Once the tanks in a treatment plant are full, there is a continuous movement of liquid in and out of the various units. As long as there is plant influent there will be treated wastewater leaving the settling tank. This occurs by the supernatant in the settling tank overflowing into a trough as shown here. The liquid which leaves a treatment unit is known as the effluent. The aeration tank effluent is the same as the settling tank influent. Flow may leave a tank through a submerged pipe such as that shown here between the aeration and settling tank. A common outlet arrangement for settling tanks is the use of an overflow trough as shown. The vertical side of the trough which controls the water surface is commonly referred to as the effluent weir.

(Tone – Slide 12) Chlorination of the settling tank effluent may be required prior to its disposal to the receiving stream or on land. The purpose of adding chlorine is to reduce the hazard of introducing disease-causing organisms into the receiving stream or underground water table. Organisms which can cause disease such as typhoid may be found in wastewater. These organisms can be killed by contact with very weak chlorine solutions in a period of 20 to 40 minutes.

The chlorine contact tank is normally the last treatment unit in the plant. The discharge from the last treatment unit is usually referred to as the plant effluent. If there was no chlorine contact tank the settling tank effluent would then become the plant effluent.

While this completes an examination of the units which treat the liquid portion of the wastewater some attention must again be directed to the solids portion.

(Tone – Slide 13) It was stated earlier that the growth of activated sludge continues as long as there is oxygen and organic food for the microorganisms. While this growth is essential to the removal of pollutants, it is possible to have too much activated sludge. As an example, as the amount of sludge in the system increases the depth of the sludge blanket in the settling tank will increase even if more sludge is returned by the airlift pump. In every plant there comes a time when sludge must be wasted. This may be done by pumping sludge to a holding tank as shown here. In some cases the sludge may be pumped onto sand beds where it is dried, or pumped to a tank truck and hauled away for disposal.

(Tone – Slide 14) It should become evident that the proper operation of an extended aeration package plant is not something that happens automatically. There is air and chlorine to be maintained and solids control to be practiced by wasting. There is a certain amount of mechanical equipment driven by electric motors which require maintenance. All of these considerations are a part of process control. To prepare for a better understanding of what is required, a more detailed examination of the mechanical features of the plant will be made.

(Tone – Slide 15) Here is an overall view of the plant and the features which we have discussed.

(Tone – Slide 16) This is a typical package wastewater treatment plant of the extended aeration type. While plants constructed by different manufacturers may look different, the basic design and principles remain the same.

This plant has recently been installed and work is not yet fully completed. The plant consists of a combination of prefabricated steel tanks and precast concrete tanks.

In the background is the comminutor and by-pass bar screen. In front of these are the aeration and settling tanks. These are prefabricated steel tanks buried in the ground. On the right is a precast concrete septic tank which is employed here as a waste sludge storage tank. In the foreground is the chlorine contact tank which is also a precast concrete structure. To the left a control building has been provided to house the air compressors, chlorination equipment, motor controls, and a small laboratory. Many plants of this type are not provided with such control buildings but they are highly desirable.

(Tone – Slide 17) Recall that raw wastewater may be passed through a comminutor before entering the plant. The comminutor cuts up or shreds solid materials found in the raw wastewater so that airlift pumps and other plant piping will not be clogged. The comminutor must be checked periodically and lubrication must be applied on a regularly scheduled basis. The manufacturer's maintenance manual should always be followed for lubrication instructions. Unless the cutting elements of these units are maintained they will not do a proper job of cutting. This can result in the comminutor jamming or shredding rags and forming them into ropes of fibrous material more objectionable than the original solids. Properly maintained, the comminutor can be a reliable, labor-saving device.

(Tone – Slide 18) A by-pass bar screen as shown here is usually provided in conjunction with a comminutor. It may be substituted for the comminutor during periods of repair or power failure.

(Tone – Slide 19) In some systems a bar screen is used instead of a comminutor. The bar screen merely strains the raw wastewater and blocks sticks, papers, and rags from entering the plant. When using a bar screen, it is necessary to periodically remove debris from the screen so that the flow of wastewater into the plant is not impeded. Debris removed from the bar screen is usually disposed of by burial. When disposing of screenings in this manner, they should be covered immediately with a minimum of 6 inches of compacted earth. This will normally be sufficient to discourage rodents from burrowing, and prevent odors, or the attracting and breeding of flies.

(Tone – Slide 20) This is the aeration compartment portion of an extended aeration plant. Notice that the mixed liquor is being thoroughly agitated by the action of air which is being pumped to the bottom of the tank and diffused. Note also the chocolate brown color of the liquid which is characteristic of a properly operating unit.

(Tone – Slide 21) Air flows from the blower through the downfeed pipe to the bottom of the aeration compartment. On reaching the bottom the air is fed out through the diffusers. As the air rises to the top of the compartment, oxygen is absorbed into the mixed liquor. This oxygen is necessary to maintain the life cycle of the microorganisms in the system. The turbulence created by the rising air provides the mixing action which combines the influent and return sludge, and maintains the sludge particles in suspension.

(Tone – Slide 22) There are two commonly encountered types of downfeed pipe assemblies. One type is a drop pipe. It is mounted in a stationary position and cannot be raised for repairs. Disassembly of the downfeed pipe is necessary if repairs are required. The flow of air is usually controlled by a valve located at the top of the downfeed pipe. The air flows down through the pipe to the diffuser nozzle where it is injected into the mixed liquor. The second type of downfeed pipe assembly operates on the same principle but it is mounted so that the downfeed pipe may be swung up when necessary. This variety is known as a swing type. There are many types of diffusers. Those shown on the drop pipe assembly are porous tubes. Those on the swing type assembly are diffuser discs. The porous tubes provide a small bubble of air while diffusers of the disc- or slotted-pipe type provide a larger bubble. The fine bubble diffusers are subject to more frequent clogging. When clogging occurs the diffusers must be cleaned. One indication of clogging is an increase of blower pressure. When it has increased to the point that the pressure relief valve is open or chattering the diffusers must be cleaned.

(Tone – Slide 23) This is a settling compartment. Notice that the water surface of this tank is quiet. There is no mixing action here. The sludge has settled and a clear liquid (usually called supernatant) remains at the surface.

(Tone – Slide 24) The sludge that settles in the settling tank is removed by means of the airlift pump. This illustrates the typical airlift pump. Air is injected into the footpiece of the vertical portion of the pump and rises to the vent at the top. The rising action of the air creates a vacuum at the pump opening on the bottom of the tank. The vacuum draws in settled sludge and carries it to the top of the vertical pipe where it is returned through a horizontal pipe to the aeration tank. The airlift pump may clog from time to time. When clogging occurs, backflushing with air or water should be used to clear the pump. If backflushing fails, rodding or removal of the pump will be necessary to correct the problem. When water is used to backflush the airlift, it is recommended that the plant effluent waster be used and not a potable public water supply.

At times the settled sludge may "hang up" on the walls of the settling tank hopper bottom. When this occurs it will be necessary to gently scrape or squeegee the sludge from the walls and toward the tank bottom.

(Tone – Slide 25) Scum on the surface of the settling tank results from floating solids in the raw wastewater and from a certain fraction of the activated sludge which will float rather than settle. These floating solids must be removed in order to prevent an odor nuisance and to keep them from passing over the effluent weir. This is accomplished by means of a surface skimmer which is operated as required. *(Tone – Slide 26)* The surface skimmer incorporates an airlift pump. The skimmer pumps floating solids and scum from the settling tank back into the aeration tank. Notice that the shape of the airlift foot piece provides for suction from the surface of the liquid. Leaves and other similar debris can easily clog any type of airlift pump, special care should be taken to prevent entry of these items into the settling tank. If these items enter the tank, manual skimming will be required. Protective screens over the settling tank may be required in particularly troublesome locations. Much of the scum pumped from the settling tank to the aeration tank is grease. As a result of the biological action in the aeration tank, some of the grease is destroyed, that which is not will roll into grease balls which grow in size. From time to time these must be removed manually from the aeration tank and disposed of by burial.

(Tone – Slide 27) It should now be apparent that many of the integral components of the extended aeration system require air in order to operate. The air source is generally provided by a blower coupled to an electric motor. Duplicate or stand-by motor-blower units are desirable and may be required by regulatory agencies.

The operating pressure of the blowers which supply the air is generally in the range of 3 to 7 pounds per square inch or psi. If the diffusers are 10 feet below the water surface the pressure will be about 5 psi. Each foot of water is approximately equal to 1/2 psi. The capacity and rated discharge pressure of the blower is usually stamped on the blower nameplate. A relief valve should be provided in the blower discharge piping and set to open slightly below the rated blower pressure.

(Tone – Slide 28) Air filters are normally provided at the suction piping inlet. It is necessary to filter the air being pumped to protect the blowers from damage and the air diffusers from clogging. The air filter must be cleaned periodically in order to maintain an unobstructed flow of air to the blower.

(Tone – Slide 29) If it ever becomes necessary to change the compressor air output rate, merely make the appropriate change in compressor sheave size. A larger sheave on the compressor will lower the compressor output. A smaller sheave will increase the volume of air produced by the compressor. Some compressors are equipped with variable speed drive equipment which allows changing the air output rate without changing sheaves.

When sheaves or belts are changed it is important that they be matched sets. If a sheave is changed on the compressor its replacement must match the sheave on the motor. If it is necessary to change one belt then all of the belts must be replaced with a matched set.

(Tone – Slide 30) Motors are protected against mechanical and electrical overloads by circuit breakers located in the control panel. Occasional tripping of the circuit breaker may occur and this will require a manual reset. If frequent tripping occurs, it will be necessary to track down the trouble and perform the needed repairs.

(Tone – Slide 31) Motors, compressors, and other mechanical equipment must be serviced on a regular basis. Equipment maintenance logs or preventive maintenance records must be kept. Frequency of oiling, greasing, and inspection must be followed to prevent even potential equipment failures. Even overlubrication can be a problem; more electric motors are damaged by overlubrication than for any other reason. Maintenance logs will help assure proper completion of necessary tasks.

(Tone – Slide 32) In small plants of the extended aeration type, chlorine is usually applied to the settling tank effluent by preparing a chlorine solution with powdered chlorine. The powder, usually calcium hypochlorite, commonly known as HTH, is dissolved in water to yield about a 1/2% ch lorine solution. This is then pumped at a rate of about 1/2 to 1 gallon per hour to the settling tank effluent. The mixture of chlorine solution and treated wastewater contains less than 1/500 of 1% chlorine but this is sufficient to kill disease-producing organisms.

The chlorine contact tank must be inspected and cleaned periodically to prevent accumulations of floating material and settled sludge.

(Tone – Slide 33) Flow measurement equipment is a valuable aid when tracking problems within the treatment plant. The installation of a weir box at some point in the plant effluent system is recommended. The effluent passes through the weir box containing a special V-Notch weir. The flow can be measured by noting the depth or head of water passing over the weir.

(Tone – Slide 34) The quantity of water passsing over the weir can be determined from charts such as this. If the depth of water above the bottom of the notch is 3¼ inches and the shape of the V forms a 90° angle, the flow rate would be 0.065 million gallons per day which is the same as 65,000 gallons per day.

(Tone – Slide 35) Flow measurements may be recorded automatically and continuously by inexpensive instruments such as this. The float senses the depth of water passing over the weir. Either by mechanical linkage or electric signal the depth is transmitted to a recorder. *(Tone – Slide 36)* The depth is recorded on a chart which is calibrated to be read in thousand gallons per day or million gallons per day. This is a chart showing the recorded rate of flow over a period of approximately eight hours. It indicates that for this period the average flow rate was 16,810 gallons per day.

(Tone – Slide 37) Another area which may require special attention is the foam that accumulates in the aeration tank. This foam is a natural by-product of the aeration process and must be controlled in order to prevent a nuisance of foam being blown onto private property. Foam is most prevalent during initial plant startup. The most common technique of controlling the buildup of foam is the water spray foam control. Using this technique, a water spray is directed at the foam knocking it down and preventing further buildup. *(Tone – Slide 38)* Plant effluent rather than fresh water may be used as the spray water. When using plant effluent as spray water or backflush water for the airlift, care should be taken to locate the pump suction so that the best quality of water is supplied. This will usually be obtained near the end of the chlorine contact tank and at about mid depth of the tank. If solids are present in the spray water, the spray nozzles will clog. This pump is mounted over the chlorine contact tank and provides water for the spray nozzles and yard hydarants.

In severe cases of foaming it may be necessary to use commercial defoaming agents.

(Tone – Slide 39) When it becomes necessary to waste sludge, the operator has several options. The point from which sludge is to be wasted can be either the aeration tank or the settling tank. The place to which sludge is wasted will also vary. It can be spread on land and dried for plowing into the soil. It may be placed on sand beds to be dried, later removed, and spread on land or buried. In some cases its ultimate disposal is not a concern of the operator. This is usually true if it is removed by tank truck.

When a sludge holding tank is provided, the sludge is usually wasted to that tank. When the holding tank has accumulated an excess of solids, they must then be disposed of by drying and land disposal or discharge to a tank truck. The holding tank must be aerated continuously except when wasting sludge to the tank. This will be discussed in more detail in Part 2.

(This concludes this portion of the presentation. Rewind this tape before removing it. To continue, insert the cassette labeled Part 2 – Process Control)

CASSETTE 2 – PART 2, PROCESS CONTROL

(Tone – Slide 40) Part 2 presents descriptions of the various indications and tests which aid the operator in maintaining a properly operating plant.

(Tone – Slide 41) In order to keep a plant operating effectively, periodic inspection is required. Some of the best indicators of plant efficiency are the color of the liquid in the aeration and settling tanks, the odor given off by the plant, and the clarity of the effluent. In the following examples keep in mind that the colors mentioned are typical and may vary from plant to plant depending on the plant size, the type of raw wastewater, and so on.

*(Tone – Slide 42)** Assuming a typical domestic wastewater, the influent would be gray in color, similar to dishwater. If the plant is operating correctly, the colors shown here would be similar to those to be found in the aeration tank, settling tank, and activated sludge return line. A musty or earthy odor would accompany this condition. Remember that all colors in these examples of plant operation are only typical and may vary from plant to plant. The following conditions may be indicative of problems other than those discussed, but the problems mentioned are some of those most commonly encountered in plants treating domestic wastewater.

(Tone – Slide 43) When a plant has been contaminated by clay or soil entering with the plant influent, a color similar to that of the clay or soil native to the area will prevail in all areas of the plant. It will not necessarily be yellowish as shown here. Also, the musty odor which is present during proper operation will be less distinguishable. In extreme cases it may be necessary to shut down the plant and clean out the clay or soil. The source of the clay or soil is usually from construction projects or sometimes from broken sewers. The source must be found and eliminated. Not only is the entrance of the soil objectionable but the ground or surface water which carries it into the system can hydraulically overload the plant and prevent its proper operation.

(Tone – Slide 44) Fresh domestic wastewater is normally gray in color and has a slight musty odor. If no air is supplied to the wastewater a bacterial action takes place different from that which has been described in the aeration tank. This action results in the wastewater turning black in color and producing offensive odors. When this occurs the wastewater is commonly referred to as being septic. Septic wastewater can cause the contents of the entire plant to go septic if sufficient air cannot be provided to overcome the septic condition. A common cause of septic wastewater is flat sewer lines in which wastewater solids settle and begin to decompose. Septic wastewater is generally acid and may have a pH possibly as low as 6.0. A low pH value of raw wastewater can also be the result of industrial wastes entering the sewer. These may cause even lower pH values.

(Tone – Slide 45) The pH is a measure of the acid or alkaline condition of a solution. The center of the scale is neutral and is given the value of 7. Numbers smaller than 8 indicate the presence of an acid. The smaller the number, the more acidic the solution is. Numbers larger than 7, up to a maximum of 14, indicate the presence of alkali. The larger the number, the more alkaline the solution is.

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*Moderators' Note: The various limitations on color quality in these slides, as projected, may result in inconsistencies with the statements in the script relative to "typical colors." This should be brought to the attention of the trainees.

(Tone — Slide 46) Domestic wastewater is usually within the pH range from 6.5 to 8.5. If the pH in the aeration tank drops below 6.5, addition of lime or sodium bicarbonate in small amounts may be required until the pH rises within the acceptable range. If the pH in the aeration tank rises above 8.5, addition of acid in small quantities may be required until the pH falls within the acceptable range. Significant pH changes from normal are a good indication that industrial wastes are being discharged into the sewer. If pH values of the plant influent are normally between 6.8 and 7.4 a pH change to 6.5 or lower would be a significant change. Similarly a pH value of 7.9 or higher would be significant.

When a septic condition occurs, or when objectionable wastewater is being received, try to determine the source and eliminate it. If the source cannot be determined, consult the state water pollution control agency for assistance.

(Tone — Slide 47) Sufficient dissolved oxygen is essential to the biological process employed in extended aeration plants. The desirable dissolved oxygen concentration is between 0.5 mg/l and 2.0 mg/l. It is uneconomical and unnecessary to maintain a concentration greater than 2.0 mg/l. The dissolved oxygen concentration will be affected by normal variations of loading on the plant. A higher concentration can be expected during low flow periods and is acceptable. In general no harm is done by dissolved oxygen concentrations higher than 2.0 mg/l, but normally they are not required for good operation. The aeration system of the plant provides control of the dissolved oxygen concentration in the aeration tank liquor.

(Tone — Slide 48) Insufficient aeration is detrimental to proper operation. This problem, if allowed to continue, will result in the plant becoming septic. Indications of insufficient aeration are the absence of dissolved oxygen and gray, murky colors accompanied by a slight septic odor resembling rotten eggs. This condition can usually be corrected by increasing aeration until proper operation is restored.

(Tone — Slide 49) Overaeration as well as insufficient aeration can also be a problem. Overaeration can be caused by improper air supply adjustment. Usually it is the result of a flow of plant influent much below the level or strength for which the plant was designed. A reddish color will be noted in all areas of the system with the exception of the influent. A reddish brown, slimy scum will often be present on the settling tank. Reduction of the air being supplied including, if necessary, intermittent operation of the compressors, can help correct the problem. Reducing the rate of return sludge can also be helpful.

(Tone — Slide 50) An improperly operating return sludge airlift pump will usually cause the color of the aeration tank to turn light brown due to failure to return activated sludge to the system. A slight foul odor is also usually apparent. If proper operation is not restored, the activated sludge held in the settling tank will go septic and septic sludge will appear on the surface as scum.

(Tone — Slide 51) An improperly operating return sludge airlift pump will be accompanied by an increase in the depth of the sludge blanket in the settling tank. If this condition is not corrected activated sludge will ultimately be lost over the settling tank effluent weir.

LESSON PLAN — SUBDIVISION 9 **TIME: 30 MINUTES**

Title: Summary, Questions and Answers

Instructor Objectives: To summarize and review the key points from the Activated Sludge Lesson, and to provide the students with an opportunity to ask questions and to clear up any points about which they may be uncertain.

Student Objective: To reinforce student objectives from other lesson subdivisions on Activated Sludge.

Training Materials:

Lesson plans — Subdivisions 1-8, Activated Sludge lesson

Training materials, Subdivisions 1-8

Classroom Set-Up:

A normal classroom set-up will be required. Students should be seated with their student groups

Chalkboard or easel

Pointer

Subdivision Schedule:

There is no set schedule for the 30 minute time period

Instructor Approach:

The instructor should ask the class for any questions and respond to them. Topics of interest to the class that have not been covered previously may be surfaced and group discussion continued as time permits. The instructor should use the last 10 minutes of the session to summarize the materials presented in the Activated Sludge Lesson plan.

LESSON OUTLINE

I. Respond to class questions

II. Summarize the Activated Sludge lesson

The instructor should briefly hit the high points from each subdivision. Title slides used in other subdivisions may be used by the instructor in putting together his summary. It is suggested that as a minimum, the following points be touched in the summary.

A. The objectives of activated sludge wastewater treatment process is to convert soluble BOD to settleable solids and produce a clear effluent low in TSS and BOD

B. The importance of gathering performance data on the facility before attempting to recommend corrective actions to apparent problems. Design data for the plant are needed and actual loading and operating data must be compared to the design before effective troubleshooting can begin

C. Activated sludge process control problems can usually be traced to poor sludge quality. A good sludge should settle fairly slowly, flocculate, compact uniformly and produce a clear effluent. Good sludge quality is achieved by establishing a proper balance of solids in the system. Process control is achieved by wasting excess activated sludge to maintain the correct solids balance, by varying return sludge rate to maintain a proper distribution of the solids between the aeration basin and final clarifier and by contolling air supply rates to maintain adequate, but not excessive, DO and mixing in the aeration basin.

D. A number of control strategies have been successful for the activated sludge process. Most useful of these are F/M, MCRT, RR and sludge settling characteristics. No one control strategy can be used as the sole basis for process control and troubleshooting in the activated sludge process. They must be considered if efficient and consistent process performance is to be achieved

KEY POINTS & INSTRUCTOR GUIDE

Guide: Note how this relates to the steps in the Process of Troubleshooting.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
E. Troubleshooter's performance will improve with experience gained by observing good operations and attempting to correct poor operations. You'll make some mistakes but don't let that deter you from trying something new. Be careful not to tamper with a good operation. If the operation is bad, you probably won't do a lot of harm by trying to correct it. If you follow a systematic approach to identifying problems, obtaining data to confirm conclusions, prioritize the solutions and implement them while monitoring the results,	Guide: Stress Troubleshooter attitude and behavior as important elements.
F. The most important ingredient in good process performance is a good operator. Your first objective in troubleshooting should be to involve the plant operator in the troubleshooting process making sure that he understnads what you've started. The easy part of troubleshooting is solving the technical problems; the hard part is training the operator to continue the programs that you, the troubleshooter, have recommended.	Key Point: Note how these points relate to what was discussed in the earlier lesson on the Elements of Troubleshooting.

STUDENT NOTEBOOK MATERIALS

The following materials are included in Section 10 of the Student Notebook, ACTIVATED SLUDGE. The Notebook is distributed to students at the start of the course, and is available to them as a reference material throughout the course. Some of these materials are to be used by the instructor as an integral part of the lesson.

Index of Notebook Materials

PAGES	MATERIAL	USE IN LESSON
AS – 1	Activated Sludge Control Strategy Cases	Reference by Instructor Subdivision 1, Section V
AS 2 – 9	Checklist for Process Evaluation	Reference by Instructor Subdivision 1, Section VI
AS 10 thru AS – 13	Process Flow Diagrams	Reference by Instructor, Subdivision 1, Section VII
AS 14 – 18	Supplemental Information on Control Concepts	Additional Information Provided to Students
AS – 19	Additional Information for Troubleshooting Problems	Reference by Instructor Subdivision 3, Section VIII
AS 20 thru 22	Hamsborough Troubleshooting Problem – Part I	Subdivision 5, Section I Used by students to solve problem
AS – 23	Answer Sheet – Hamsborough Troubleshooting Problem	Subdivision 5, Section II
AS – 24 thru 36	Pullman Troubleshooting Problem	Subdivision 6 – Used by students to solve and review problem
AS – 37 thru 39	Studies & Tables on Package Plants	Reference by Instructor Subdivision 8, Section III
AS – 40	Troubleshooting Guide – Extended Aeration Plants	Reference by Instructor Subdivision 8, Section IV
AS – 41	Package Plant Checklist	Same as above
AS – 42 46	Flow Diagrams – Package Plants	Reference by Instructor Subdivision 8, Section I
AS – 47	References	

ACTIVATED SLUDGE CONTROL STRATEGY CASES

1. *Case I:* Assume that the hydraulic and organic loads to the aeration basin remain constant. Settleometer test results indicate that the sludge is beginning to settle more slowly and return sludge concentrations are decreasing. Indicate below what the expected change in each parameter would be:

   a. F/M
   b. MCRT
   c. Respiration rate of the MLSS

   Indicate below the control actions that would probably be required

   a. Return sludge flow rate
   b. Waste sludge rate

2. *Case II:* Assume that the hydraulic load to the aeration basin remains constant and that the organic load increases. Assume that no changes have been made in return rates or in wasting practices. Indicate below the expected change in each parameter.

   a. Sludge settling rate
   b. Sludge blanket depth
   c. F/M
   d. MCRT
   e. Respiration rate of the MLSS
   f. Aeration basin DO

   Indicate below the control actions that would probably be required:

   a. Return sludge rate
   b. Waste sludge rate
   c. Air supply rate

3. *Case III:* Assume that the hydraulic flow to the aeration basin increases while the organic load remains constant. Indicate below what the expected change in each parameter would be:

   a. MLSS concentration
   b. F/M
   c. MCRT
   d. Respiration rate of the MLSS
   e. Sludge settling rate
   f. Sludge blanket depth

   Indicate below the probable control actions that would be required

   a. Sludge return rate
   b. Waste sludge rate

ACTIVATED SLUDGE PROCESS EVALUATION

Treatment Facilities

PLANT NAME ______________________________ **SUPERVISOR** __________

Location – City ______________________________ **State** ______________

Phone No. ________________________

DATE OR PERIOD ____________________________

OPERATING MODE
(Step, Complete Mix, etc.) . . . .

AERATION TANKS
(Air, O_2, Mech., etc) . . . .

No. of Tanks Available . . . .
No. of Passes/Tank . . . .
Tank Dimensions . . . .
ASA – Surface Area/Tank (sq ft) . . . .
AVF – Volume/Tank (cu ft) . . . .
AVG. – Volume/Tank (gals) . . . .

No of Tanks in Service . . . .
ASA – Total Surface Area (sq ft) . . . .
AVF – Total Volume (cu ft) . . . .
AVG. – Total Volume (gals) . . . .

FINAL CLARIFIERS
(Rectangular or Circular)
(Center or Peripheral Feed)
(Effluent Launder Arrangement)
(Sludge Mech. – Plows, Suction, etc) . . . .

No. of Tanks Available . . . .
Tank Demensions . . . .
CSA – Surface Area/Tank (sq ft) . . . .
CVF – Volume/Tank (cu ft) . . . .

No. of Tanks in Service. . . . .
CSA – Total Surface Area (sq ft) . . . .
CVF – Total Volume (cu ft). . . . .
CVG – Total Volume (gals) . . . .

PLANT NAME ______________________________ **SUPERVISOR** __________

Location – City ______________________________ **State** ______________

Phone No. ____________________

DATE OR PERIOD ___________________________

AERATION EQUIPMENT – DIFFUSED AIR
Diffusers
(Spargers, Plates, etc)
(Diffuser Placement – Spacing) . . . .

Blowers
(Type – Centrif., Positive Displacement, etc) . . . .
No. Available . . . .
Total SCFM Available . . . .

AERATION EQUIPMENT – MECHANICAL
(Surface, Turbine, etc)
(Adjustable Speed or Weirs?) . . . .
No. of Aerators Available . . . .
HP per Aerator . . . .
Total HP Available . . . .

RETURN SLUDGE PUMPS
Type (Centrif., Airlift, etc) . . . .
(Variable or Constant) . . . .
No. of pumps . . . .
Capacity – MGD/pump . . . .
Total Available Capacity (MGD) . . . .

WASTE SLUDGE PUMPS
Manifold from Return? . . . .
Separate Pumps? . . . .
Type (Centrif., Piston, etc) . . . .
(Variable or Constant) . . . .
No. of Pumps . . . .
Capacity – MGD/pump . . . .
Total Available Capacity (MGD) . . . .
Suction from ML and/or Clar. Sl. Piping . . . .

PLANT NAME ______________________________ **SUPERVISOR** __________

Location – City ______________________________ **State** ______________

Phone No. ______________________

DATE OR PERIOD ______________________________

FLOW METERS
Describe
(Are ranges and accuracy OK?) . . . .
Locations, Types
(totalizers, chart recorders, etc) . . . .
Other sensors
(DO, pH, Sl. conc., etc) . . . .

CONTROLLERS
Describe . . . .
Automatic Controllers, if any . . . .

ACTIVATED SLUDGE PROCESS EVALUATION

Secondary Process Loadings

PLANT NAME ______________________________ **SUPERVISOR** __________

Location – City ______________________________ **State** ______________

Phone No. ____________________

DATE OR PERIOD
(Daily, Weekly or Monthly Averages) . . . .

AFI – INFLUENT TO SECONDARY PROCESS
Average Flow (MGD) . . . .
BOD$_5$ (mg/l) . . . .
BOD$_5$ (lbs/day) . . . .
TSS(mg/l) . . . .
TSS (lbs/day) . . . .
RSF – Return Sludge Flow (MGD) . . . .
RSP – Return Sludge Flow Percentage
(% of AFI)

SLUDGE CHARACTERISTICS
(Mixed Liquor)
MLTSS (mg/l) . . . .
ATC – Aeration Tank Conc. (%) . . . .
WCR – MLTSS/ATC . . . .
% Volatile . . . .

AERATION TANK LOADINGS
(Hydraulic)
ADT @ AFO – Aeration Detention Time @ Waste Flow
ADT @ TFL – Aeration Detention Time @ Influent
Flow + Return (hrs) . . . .
ASDT – A.T. Sludge Detention Time (hrs) . . . .
AWDT – A.T. Waste Detention Time (hrs) . . . .

(Organic)
lbs. BOD$_5$/1,000 cu ft Aer. Tank . . . .
F/M – lbs BOD$_5$/lb MLVSS . . . .

(Aeration Intensity)
- Mech. or Turbine

HP Applied . . . .
HP/1,000 sq ft Aer. Surface Area . . . .
HP – Hr/lb BOD$_5$ . . . .
lb 0_2/hp-hr

PLANT NAME ______________________________ **SUPERVISOR** __________

Location – City ______________________________ **State** __________

Phone No. ____________________

DATE OR PERIOD
(Daily, Weekly or Monthly Averages) . . . .

- Atmospheric Air

SCFM – Applied . . . .
SCFM/1,000 sq ft Aer. Surface Area . . . .
cu ft/gal (Domestic Wastewater Treated) . . . .
cu ft/lb BOD removed . . . .

FINAL CLARIFIER LOADINGS
(Hydraulic)
CDT – Final Clar. Detention Time (hrs) . . . .
OFR – F.C. Surface Overflow Rate (gpd/sq ft) . . . .
Weir Overflow Data (gpd/lin ft) . . . .
Liquid Rise Rate (ft/hr) . . . .
Surface Area – Weir-Length Ratio (sq ft/ft) . . . .

(Sludge)
Solids Loading (lb MLTSS/day/sq ft) . . . .
CSDT – F.C. Sludge Detention Time (hrs) . . . .
BLT – Sludge Blanket Thickness (ft) . . . .

PROCESS CHARACTERISTICS
lbs TSS under Aeration . . . .
lbs TSS in Final Clar . . . .
lbs TSS in system . . . .

Sludge Wasted Intent. (MGD) . . . .
Sludge Wasted Intent. (lbs/day) . . . .

F.E. TSS (mg/l) . . . .
F.E. TSS (lbs/day) . . . .

Total Sludge Wasted per day (lbs/day) . . . .
(Intentional Wasting + Effluent Solids) . . . .

Sludge Age (days) . . . .

Aeration Tank DO (mg/l) . . . .

PLANT NAME ______________________ **SUPERVISOR** __________

Location – City ______________________ **State** __________

Phone No. ______________________

DATE OR PERIOD
(Daily, Weekly or Monthly Averages) . . . .

Mixed Liquor Settling & Compaction

SSV_5 ______________________ SSC_5 ______________________
SSV_{30} ______________________ SSC_{30} ______________________
SSV_{60} ______________________ SSC_{60} ______________________
SSV_{120} ______________________ SSC_{120} ______________________
SVI ______________________ RSC ______________________

PROCESS PERFORMANCE

Clarifier Effluent Turbidity (JTU, FTU or NTU) . . . .
Influent TSS (mg/l) . . . .
Efffluent TSS (mg/l) . . . .
% Reduction (%) . . . .

Influent Total BOD_5 (mg/l) . . . .
Effluent Total BOD_5 (mg/l) . . . .
% Reduction (%) . . . .

Influent Soluble BOD_5 (mg/l) . . . .
Effluent Soluble BOD_5 (mg/l) . . . .
% Reduction (%) . . . .

Influent Total COD (mg/l) . . . .
Effluent Total COD (mg/l) . . . .
% Reduction (5) . . . .

Influent Soluble COD (mg/l) . . . .
Effluent Soluble COD (mg/l) . . . .
% Reduction (%) . . . .

Influent NH_3 (mg/l) . . . .
Effluent NH_3 (mg/l) . . . .

Influent NO_3 (mg/l) . . . .
Effluent NO_3 (mg/l) . . . .

PLANT NAME ______________________ **SUPERVISOR** __________

Location – City ______________________ **State** __________

Phone No. ______________________

REMARKS & FLOW DIAGRAM

ACTIVATED SLUDGE PROCESS EVALUATION

Additional Information

PLANT NAME ______________________ **SUPERVISOR** ____________

Location — City ______________________ **State** ____________

Phone No. ________________

PRIMARY TREATMENT FACILITIES
(Rectangular or Circular) . . . .
(Center or Peripheral Feed) . . . .
(Effluent Launder Arrangement) . . . .
(Sludge Mech — Flows, Suction, etc) . . . .

No. of Tanks Available . . . .
Tank Dimensions . . . .
CSA — Surface Area/Tank (sq ft) . . . .
CVF — Volume/Tank (cu ft) . . . .
CVG — Volume/Tank (gals) . . . .

No. of Tanks in Service . . . .
CSA — Total Surface Area (sq ft) . . . .
CVF — Total Volume (cu ft). . . . .
CVG — Total Volume (gals) . . . .

INFLUENT TO PRIMARY PROCESS
Average Flow (MGD) . . . .
BOD_5 (mg/l) . . . .
BOD_5 (lb/day) . . . .
TSS (mg/l) . . . .
TSS (lb/day) . . . .

PRIMARY CLARIFIER DETENTION TIME
@ Average Influent Flow (hrs) . . . .

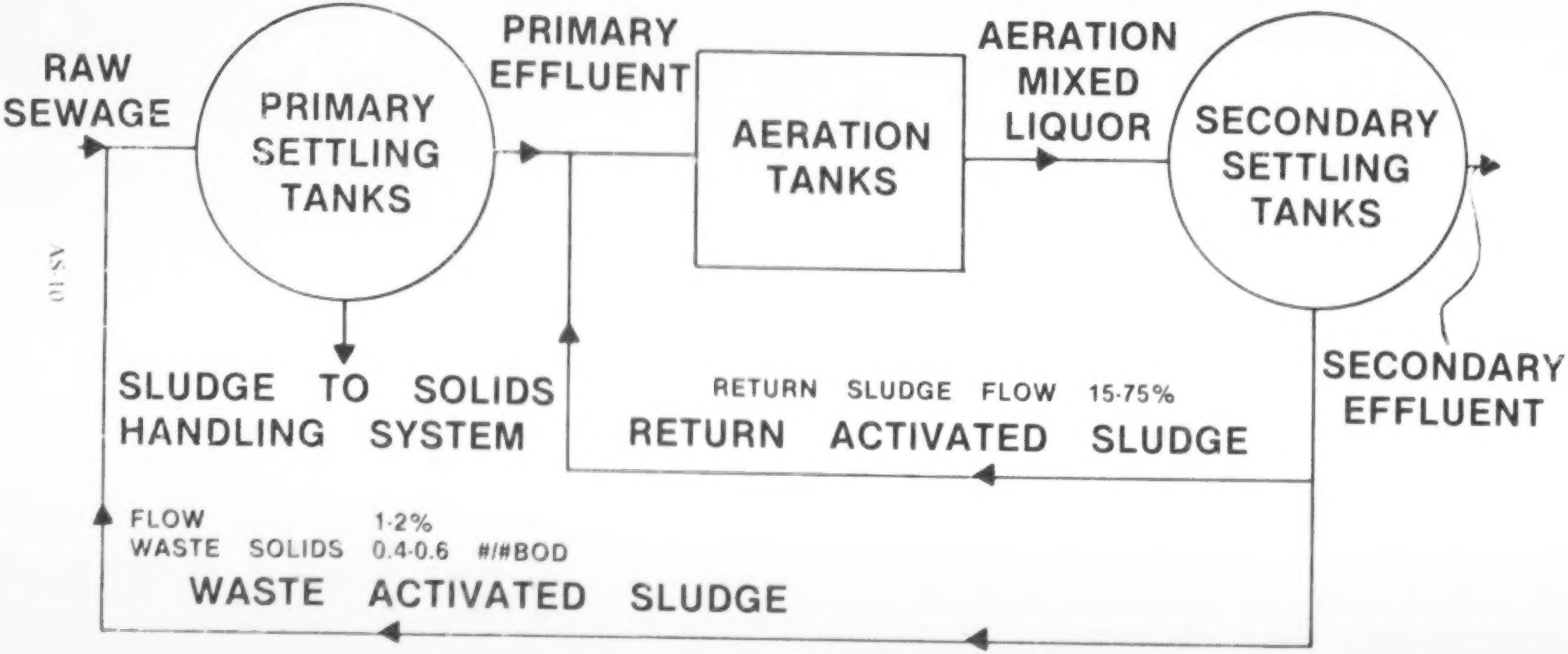
PRIMARY CLARIFIER EFFLUENT
BOD_5 (mg/l) . . . .
BOD_5 (lbs/day) . . . .
TSS (mg/l) . . . .
TSS (lbs/day) . . . .

REDUCTIONS
BOD_5 (%) . . . .
TSS (%) . . . .

Does Primary Effluent differ from Secondary Influent (AFT)? What are Recycled Floc, if any?
Disposition of Primary Sludge?
Describe Sludge Handling Facilities

DETENTION TIME	4-8 HR.
LOADING	30-40 #BOD/1,000 FT^3
F/M	0.2-0.5 #BOD/#MLVSS
AIR	750-1,000 FT^3/#BOD
SLUDGE AGE	4-6 DAYS

OVERFLOW RATE	800-1,000 GPD/FT^2
DETENTION TIME	1-3 HR.



RAW SEWAGE

PRIMARY SETTLING TANKS

PRIMARY EFFLUENT

AERATION TANKS

AERATION MIXED LIQUOR

SECONDARY SETTLING TANKS

SECONDARY EFFLUENT

SLUDGE TO SOLIDS HANDLING SYSTEM

RETURN SLUDGE FLOW 15-75%

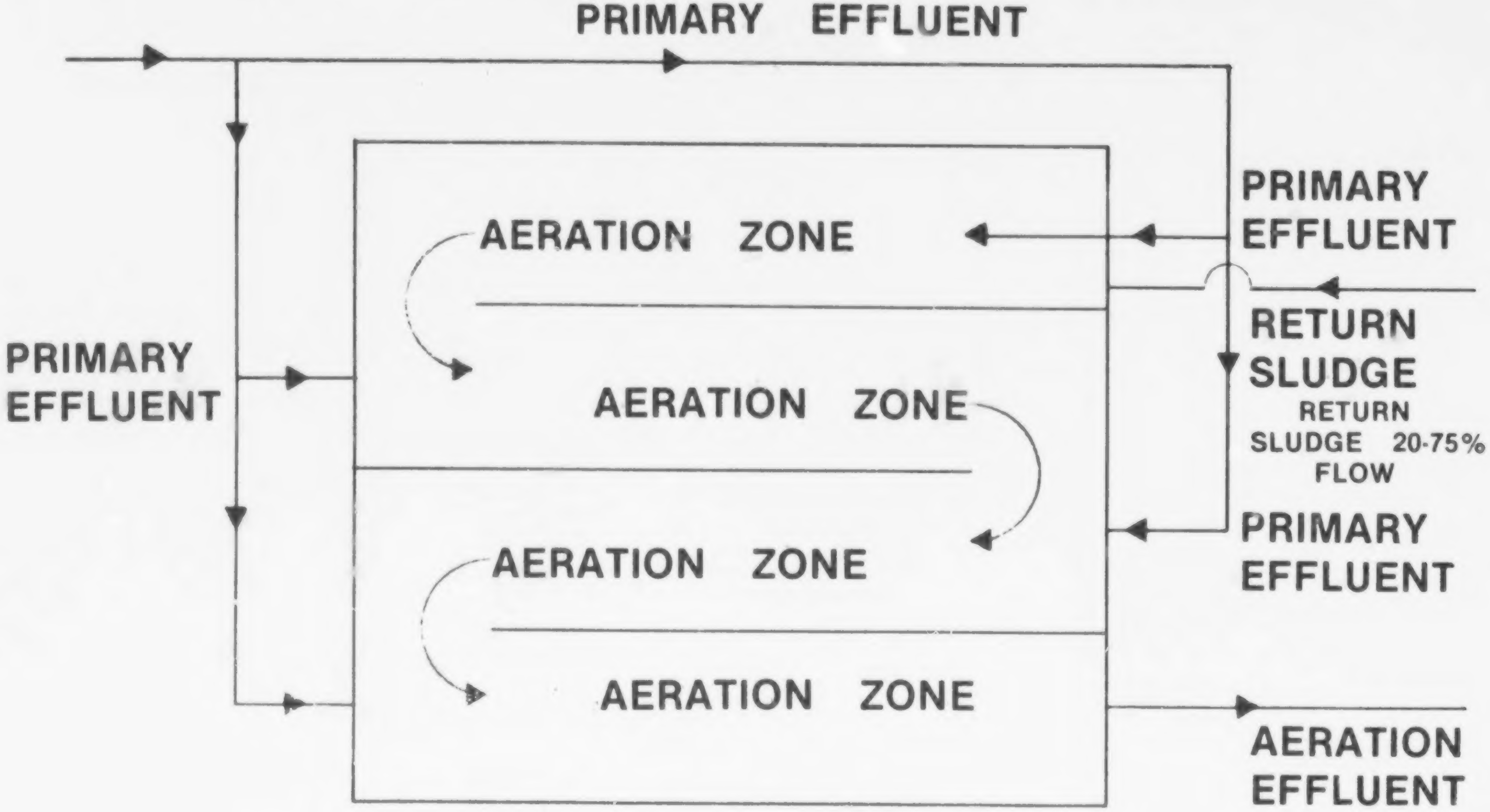
RETURN ACTIVATED SLUDGE

FLOW	1-2%
WASTE SOLIDS	0.4-0.6 #/#BOD

WASTE ACTIVATED SLUDGE

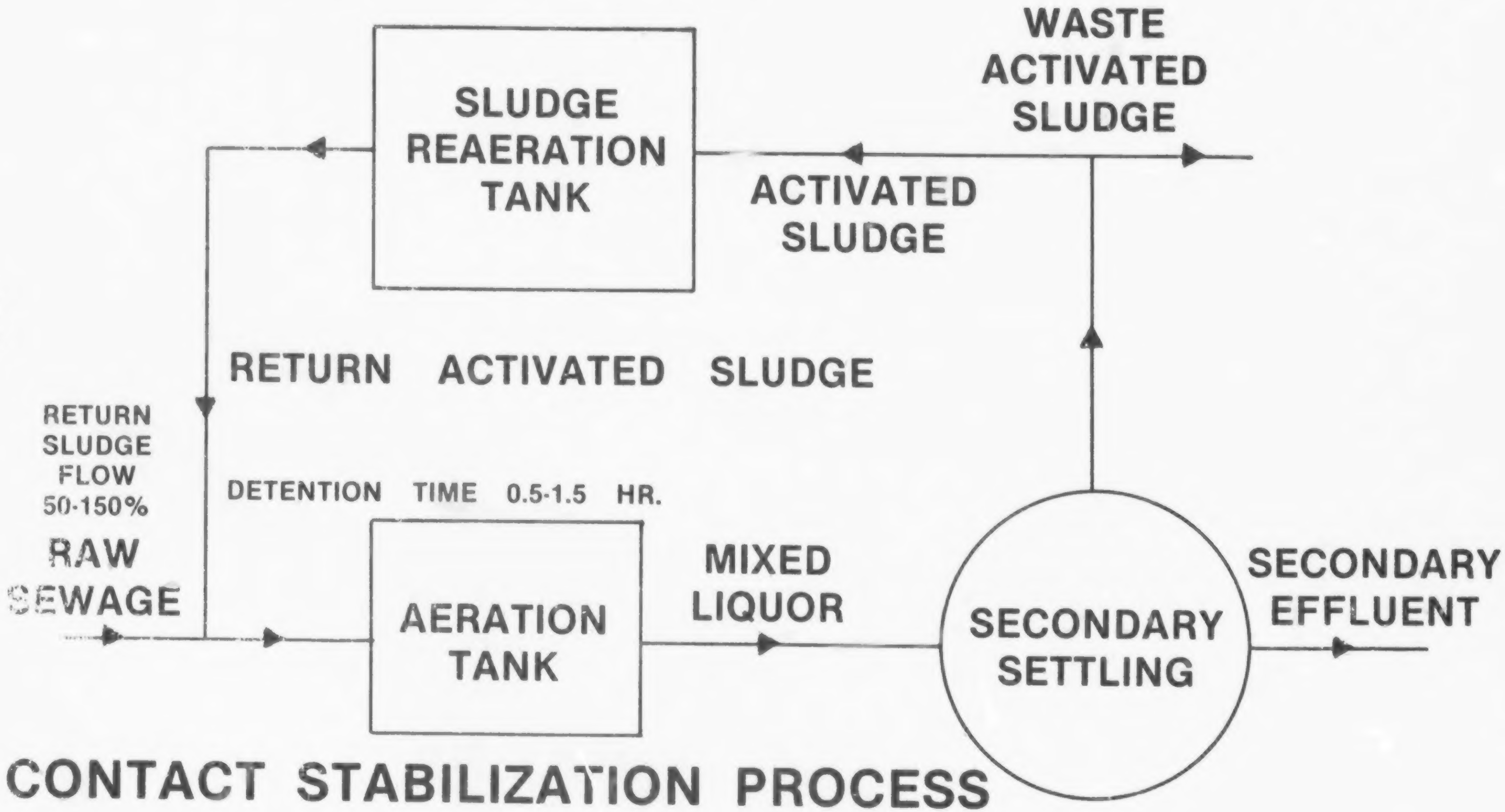
CONVENTIONAL ACTIVATED SLUDGE PROCESS

DETENTION TIME	3-8 HR.
LOADING	40-60 #BOD/1,000 FT^3
F/M	0.2-0.5 #BOD/#MLVSS
AIR FLOW	500-700 FT^3/#BOD


PRIMARY EFFLUENT
PRIMARY EFFLUENT
PRIMARY EFFLUENT
RETURN SLUDGE
RETURN SLUDGE 20-75% FLOW
PRIMARY EFFLUENT
AERATION ZONE
AERATION ZONE
AERATION ZONE
AERATION ZONE
AERATION EFFLUENT

STEP AERATION ACTIVATED SLUDGE PROCESS

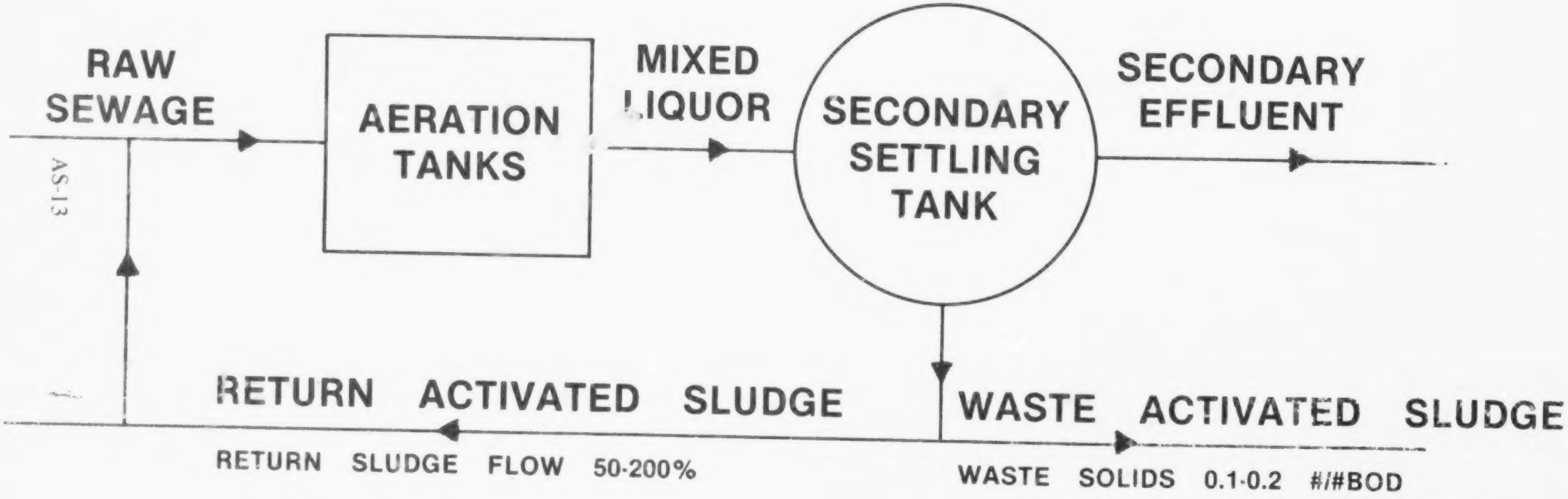
DETENTION TIME 4-8 HR.
LOADING 35-70 #BOD/1,000 FT^3 (COMBINED VOLUME)
F/M 0.2-0.5 #BOD/#MLVSS (CONTACT TANK)
AIR FLOW 750-1,500 FT^3/#BOD


WASTE ACTIVATED SLUDGE
SLUDGE REAERATION TANK
ACTIVATED SLUDGE
RETURN ACTIVATED SLUDGE
RETURN SLUDGE FLOW 50-150%
DETENTION TIME 0.5-1.5 HR.
RAW SEWAGE
AERATION TANK
MIXED LIQUOR
SECONDARY SETTLING
SECONDARY EFFLUENT

CONTACT STABILIZATION PROCESS

DETENTION TIME	16-24 HR.
LOADING	10-15 #BOD/1,000 FT^3
F/M	0.01-0.08 #BOD/#MLVSS
AIR FLOW	2,000-2,500 FT^2/#BOD

OVERFLOW RATE 300-600 GPD/FT^2



RAW SEWAGE

AERATION TANKS

MIXED LIQUOR

SECONDARY SETTLING TANK

SECONDARY EFFLUENT

RETURN ACTIVATED SLUDGE

RETURN SLUDGE FLOW 50-200%

WASTE ACTIVATED SLUDGE

WASTE SOLIDS 0.1-0.2 #/#BOD

EXTENDED AERATION PROCESS

SUPPLEMENTAL INFORMATION ON CONTROL CONCEPTS

For Students' Use and Reference

A. Food to Microorganism Ratio (F/M)

1. Defined as the pound of BOD removal per day per pound of mixed liquor suspended solids in the aeration basin. Can also define in terms of other analyses such as COD, TOC, TOD, MLVSS, etc., but numbers will be different depending on the analyses used for process control.

2. Advantages of the system of control is that it attempts to balance the incoming food load to the mass of biological solids in the aeration system. Control is achieved by *wasting* activated sludge. Increased wasting increases the F/M. Decreased wasting decreases the F/M.

3. Disadvantages are the need to perform complex time-consuming analyses to calculate the F/M. Does not consider solids in the clarifier. F/M then becomes more a long-range control strategy to maintain a proper quantity of solids in the system. Works best when coupled with another control strategy, such as MCRT.

4. The F/M number used for process control must be optimized for each process plant individually. There is no universal number which applies to all plants although most operate best in the 0.2 – 0.5 lb BOD removed per lb MLSS per day. The F/M for a particular plant must be determined experimentally by trying a series of F/M operating points and then selecting that F/M which gives the best effluent quality.

5. When using F/M control it is best to base control change decisions on a 5- or 7-day moving average rather than on the day-to-day values.

B. Mean Cell Residence Time (MCRT)

1. Defined as the time in days that an average cell remains in the aeration basin. Calculated by dividing the pounds of mixed liquor solids by the pounds of solids wasted per day (waste activated sludge plus effluent suspended solids).

2. Advantages are that it requires only single laboratory measurement for suspended solids and is very easy to implement.

3. Disadvantages include failure to consider the organic load on the system and the solids in the final clarifier. Most effective when used in conjunction with the F/M for process control.

4. The MCRT chosen for a given plant must be determined experimentally. The MCRT number used is the value which produces the best effluent quality. Most conventional activated sludge processes operate with an MCRT of 5 – 8 days; extended aeration MCRT may be as long as 15 – 30 days.

5. As with F/M, control decisions should be based on the 5- or 7-day moving average rather than on instantaneous day-to-day measurements.

C. Sludge Retention Time (SRT)

   1. Defined as the total solids in the system (aeration basin plus final clarifier) divided by the solids wasted per day (waste activated sludge plus effluent solids).

   2. Advantages and disadvantages are very similar to those cited for the MCRT strategy.

   3. Added disadvantage is that it considers the solids in the final clarifier but does not consider how the suspended solids are distributed between the clarifier and the aeration basin.

   4. Proper SRT value is determined experimentally.

   5. Control decisions should be based on 5- or 7-day moving averages rather than instantaneous day-to-day values.

D. Sludge Age (SA)

   1. Sludge age is defined as the pounds of suspended solids in the aeration system divided by the pounds of suspended solids in the primary effluent per day.

   2. Sludge Age is an empirical control parameter developed by Gould as a control parameter for his treatment plant. There is no theoretical basis to support the validity of this control concept; hence it will not be discussed further.

E. Constant Mixed Liquor Suspended Solids (MLSS)

   1. With this strategy, a MLSS concentration which produces a good effluent quality is determined and process control is achieved by holding the MLSS constant. Control is achieved by varying the waste activated sludge rate.

2. Advantage of the system is simplicity. One analysis is made at the same time each day and the quantity of sludge to be wasted is calculated and the waste rate adjusted accordingly.

3. Disadvantages to this strategy are many. It does not consider variations in organic or volumetric load. It does not consider solids in the clarifier. It requires that influent conditions be fairly constant from day to day and that samples be taken from the same point and at the same time each day. Many operators consider this to be among the most unreliable methods of process control.

4. MLSS concentration is controlled by varying the waste rate.

F. Respiration Rate (RR) or Oxygen Uptake Rate

1. The RR is defined as the mg/l/min of oxygen consumed per gram of MLSS. RR must be determined for several different sludge-raw wastewater effluent mixtures as indicated below:

   a. Mixed liquor sample as it leaves the aeration basin
   b. Return activated sludge diluted with final effluent
   c. Return activated sludge diluted with primary effluent or raw wastewater

2. There are many advantages to the RR as a control parameter:

   a. It gives a rapid measure of influent organic load and its biodegradability

   b. It indicates the presence of toxic or inhibitory wastes

   c. It indicates the condition of the return sludge

   d. It indicates the degree of "stability" of the final effluent and the MLSS entering the final clarifier

   e. It permits calculation of oxygen demand rates at various points in the aeration basin and hence closer control of air application rates

   f. It provides information to control both return and waste rates

3. Disadvantages of the RR as a control strategy include:

   a. Several samples must be collected, analyzed, and evaluated

   b. The test procedure requires sophisticated and relatively time-consuming laboratory procedures

   c. A great deal of experience is required to effectively interpret the results of the tests and to apply them

4. The proper RR values for the various points in a given treatment plant must be determined experimentally. The RR for mixed liquor leaving the aeration basin is normally in the range 12 - 16 mg/l/min/gm MLSS. This range is normally associated with good BOD removal and a sludge which settles well.

5. RR provides information which permits control of both waste rate and return rate from the final clarifier. Some of the information which can be obtained from RR data includes:

   a. Increasing RR at the effluent of the aeration basin could indicate increasing organic load, increasing hydrualic load and lower aeration basin detention time, or decreasing MLSS (increasing F/M). By combining this data with the RR data on the primary effluent and flow rate appropriate decision to increase or decrease return and/or waste rates could be made.

   b. Decreasing RR at the effluent of the aeration basin could indicate decreasing organic load, decreasing hydraulic load, or increasing MLSS (decreasing F/M). Again, looking at this RR and influent data, decisions on changes required in return or waste rates can be made.

6. Additional information of the use of RR for activated sludge process control can be found in the EPA slide tape XT-43 "Dissolved Oxygen in Activated Sludge" by F.J. Ludzack available on loan from EPA's National Training Center in Cincinnati, Ohio.

G. Sludge Quality

1. Sludge quality was discussed previously and the characteristics of good and bad sludge quality were reviewed. Key point to keep in mind is that all process control strategies discussed above have a single objective: achieve and maintain good sludge quality which produces a highly purified effluent, settles well, and concentrates in the final clarifier.

2. Sludge quality control concepts were pioneered by Mallory in the thirties and have been significantly advanced and improved by West. The pamphlet series that was included in your handout materials is an indepth discussion of sludge quality control as practiced by Mr. West. Trainees should be asked to read these pamphlets carefully and to pose any questions related to them after they have read them.

3. Sludge quality control is based on the concept that the sludge settling characteristics will change as activated sludge process conditions change. A change in influent organic load, influent hydraulic load, sludge retention time in the aeration basin, MLSS concentration, return sludge flow rate, etc, will affect the settling and concentration characteristics of the sludge. The sludge settling rate and concentration rate are very sensitive indicators of changes in process condition and can be used to indicate process control actions needed to maintain good system performance. Combining the data from sludge settling and concentration measurements with the data from F/M and MCRT control provides a very powerful tool to control the activated sludge process.

4. An advantage to sludge quality control is the simplicity of the test procedures. Settling rates are measured in a settleometer and concentrations of MLSS and return sludge are measured with the centrifuge. The complete testing series can be completed in about one hour. This permits the operator to do his tests more frequently and obtain better and more consistent control of the process. The test procedures are discussed in the West pamphlet series in Part II.

ACTIVATED SLUDGE

Additional Information for Troubleshooting Problems – Subdivision 3

Problem 1

a. F/M = 0.6
b. Settling: 5 min 950
30 min 750
60 min 580
c. Q = 40 MGD
d. MLSS = 1,200 mg/l
e. RAS = 4,200 mg/l
f. Reaeration is possible
g. Return rate = 40%

Problem 2

a. MCRT = 14 days
b. F/M = 0.13
c. MLSS = 4,200 mg/l
d. RAS = 12,600 mg/l
e. Settling: 5 min 630
30 min 360
60 min 330
f. There has been no sludge waste in 7 days

Problem 3

a. MCRT = 15 days
b. F/M = 0.07
c. Q = 0.3 MGD
d. RAS = 3,480 mg/l
e. MLSS = 2,400 mg/l
f. % RAS = 160%
g. Settling: 5 min 405
30 min 140
60 min 115

ACTIVATED SLUDGE – SUBDIVISION 5

Hamsborough Troubleshooting Problem – Part 1

You, as newly appointed District Engineer for your State's Department of Environmental Protection, are preparing to inspect the Municipal Wastewater treatment plant at Hamsborough. As your first step, you search through your predecessor's files but can find only limited information on the facility; there has been no previous inspection of the Hamsborough facility. However, by digging further into the files you do find some information on the community and the plant.

Hamsborough is a small suburban community with a population of about 15,000 with some light industry, mostly trucking and warehousing operations. There are two significant industrial dischargers to the system, a small printing plant which specializes in novelty printing and a meat processing and packaging plant.

A schematic flow diagram of the Hamsborough Wastewater Plant is shown on page AS-22. The major plant units are: a primary clarifier, followed by a single stage high rate trickling filter, followed by a complete mixing activated sludge plant with final clarifiers, and a chlorination system for disinfecting the final effluent. Two anaerobic digesters are used in series to handle all the sludge removed from the treatment facilities.

The original treatment plant consisted only of the primary clarifier and a trickling filter. Due to high organic loads from the meat packing plant, the design hydraulic loading is 2.1 MGD but the design population equivalent is 45,000. In the last few years the packing plant has become mainly a meat processing operation and the wastes received from the plant carry much less organic material than was previously received. The meat processing plant has its own primary clarifier which removes some of the solids and grease before the sewage enters the treatment facility.

At the treatment site the primary treated meat packing wastes combine with the raw sewage from Hamsborough and then enter the primary treatment units. The primary clarifier is a rectangular tank approximately ninety feet long and forty feet wide. Primary sludge is scraped along the bottom of the tank to the head end where it is collected into a sludge hopper. Sludge is then pumped to the primary digester. Waste activated sludge, which includes trickling filter solids since there is no intermediate clarifier, also enters the primary clarifier and is pumped with the primary sludge to the primary digester. Supernatant from the digesters and from the drying beds is returned to the primary clarifier. Digested sludge is pumped out to the drying beds.

Effluent from the primary tank is pumped to a trickling filter. A portion of the trickling filter effluent is returned back to the wet well and is recycled through the filter. The flow pumped to the trickling filter is held at a constant rate by regulating the amount of filter effluent entering the wet well.

The trickling filter effluent not recirculated to the wet well enters the aeration system. There are essentially two identical activated sludge treatment units, and the flow is split between the east unit and the west unit. The aeration system is a package process which is essentially a high-rate complete mixing activated sludge rapid-bloc process. The aeration tank and final clarifiers have a common wall. Activated sludge enters the final clarifiers through ports between the clarifiers and aeration tanks. There are three airlift pumps for each unit to waste excess sludge. The settled activated sludge in the clarifiers is returned through a chimney type opening to the aeration basin. The driving force for the return sludge is primarily due to the upward lift action of the air diffusers in the adjacent aeration tanks — a principle much like that of an airlift pump.

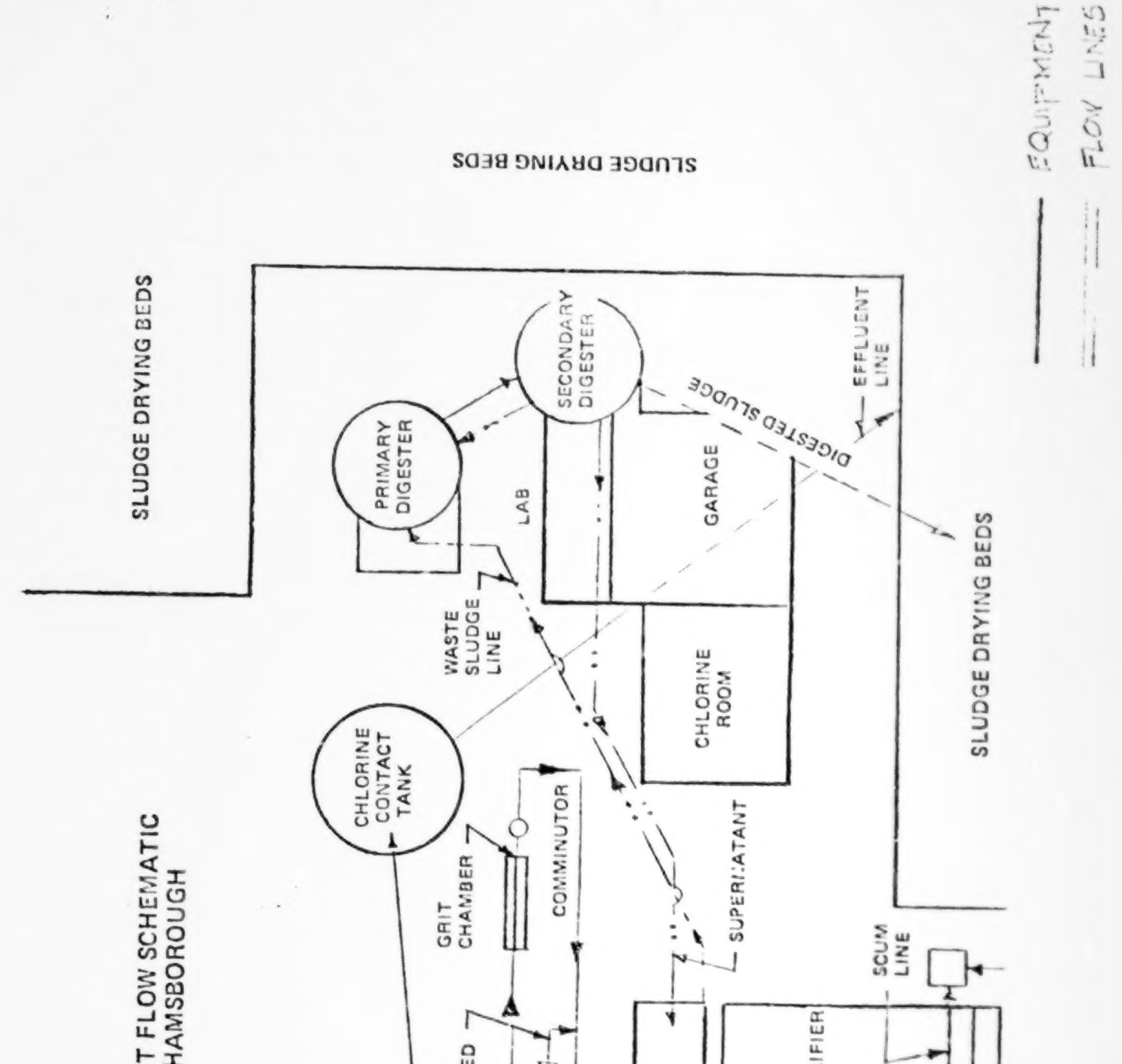
Clarified sewage passes over the weirs of the clarifiers to the effluent troughs and into a chlorine contact basin. The chlorine contact basin is a converted primary clarifier. Chlorine is introduced into the inlet pipe just prior to the introduction to the clarifier. The solids scraping mechanism of the clarifier is still intact. Disinfected sewage overflows the weirs, enters the discharge pipe and is discharged into Hamm Creek.

Performance data submitted to the state agency on monthly reports for the previous six months are summarized below:

Month	Flow, mgd			BOD_5 mg/l	TSS mg/l	Cl_2 mg/l
	Avg.	Max.	Min.			
September	2.12	2.55	1.83		13	0.4
October	2.14	2.52	1.84	14	19	0.5
December	1.59	1.87	1.23	8	18	0.5
January	1.80	2.25	1.30	7	20	0.5
February	1.70	1.83	1.52	7	14	0.5
March	1.63	1.74	1.48	12	19	0.5

Briefly review and answer the four questions that appear on the answer sheet in your Notebook under Part I.

PLANT FLOW SCHEMATIC HAMSBOROUGH


SLUDGE DRYING BEDS
SLUDGE DRYING BEDS
SLUDGE DRYING BEDS
PRIMARY DIGESTER
SECONDARY DIGESTER
EFFLUENT LINE
DIGESTED SLUDGE
LAB
GARAGE
CHLORINE ROOM
WASTE SLUDGE LINE
CHLORINE CONTACT TANK
GRIT CHAMBER
COMMINUTOR
SUPERNATANT
SCUM LINE
WASTE ACTIVATED SLUDGE
PRIMARY CLARIFIER
WASTE SLUDGE PICK-UP
FINAL CLARIFIER
E. AERATION BASIN
W. AERATION BASIN
FINAL CLARIFIER
Return Sludge Lines
BLOWER BUILDING
RECIRCULATION LINE
BYPASS
MEAT PACKING EFFLUENT
TRICKLING FILTER
DOMESTIC INFLUENT
EQUIPMENT
FLOW LINES

ACTIVATED SLUDGE – SUBDIVISION 5

Hamsborough Troubleshooting Problem – Answer Sheet

Student Group ____________________

Part I

1. Describe the steps you would take in approaching the inspection of the Hamsborough Plant.

2. Name the locations within the plant where you would have sample collected.

3. What data would you seek through sampling?

4. What are your preliminary judgments about the plant prior to your visit?

Part II

The instructor will assume the role of plant operator, and will answer any questions you may have.

5. Based on all of the observations made, indicate what your next steps would be in troubleshooting this plant. In proceeding through this portion of the exercise you are aware that the current NPDES permit for the facility requires an effluent which meets a 30 mg/l BOD and 30 mg/l TSS standard. In June, the State will revise the permit and the facility will be required to meet a 20/20 standard.

6. What actions will you take or recommend for this plant to meet the new, more stringent standard?

7. Which data would you collect and analyze before you make your final recommendation?

8. Prioritize alternatives and best solutions.

ACTIVATED SLUDGE – SUBDIVISION 6

City of Pullman, Sewage Treatment Plant
Department of Public Works

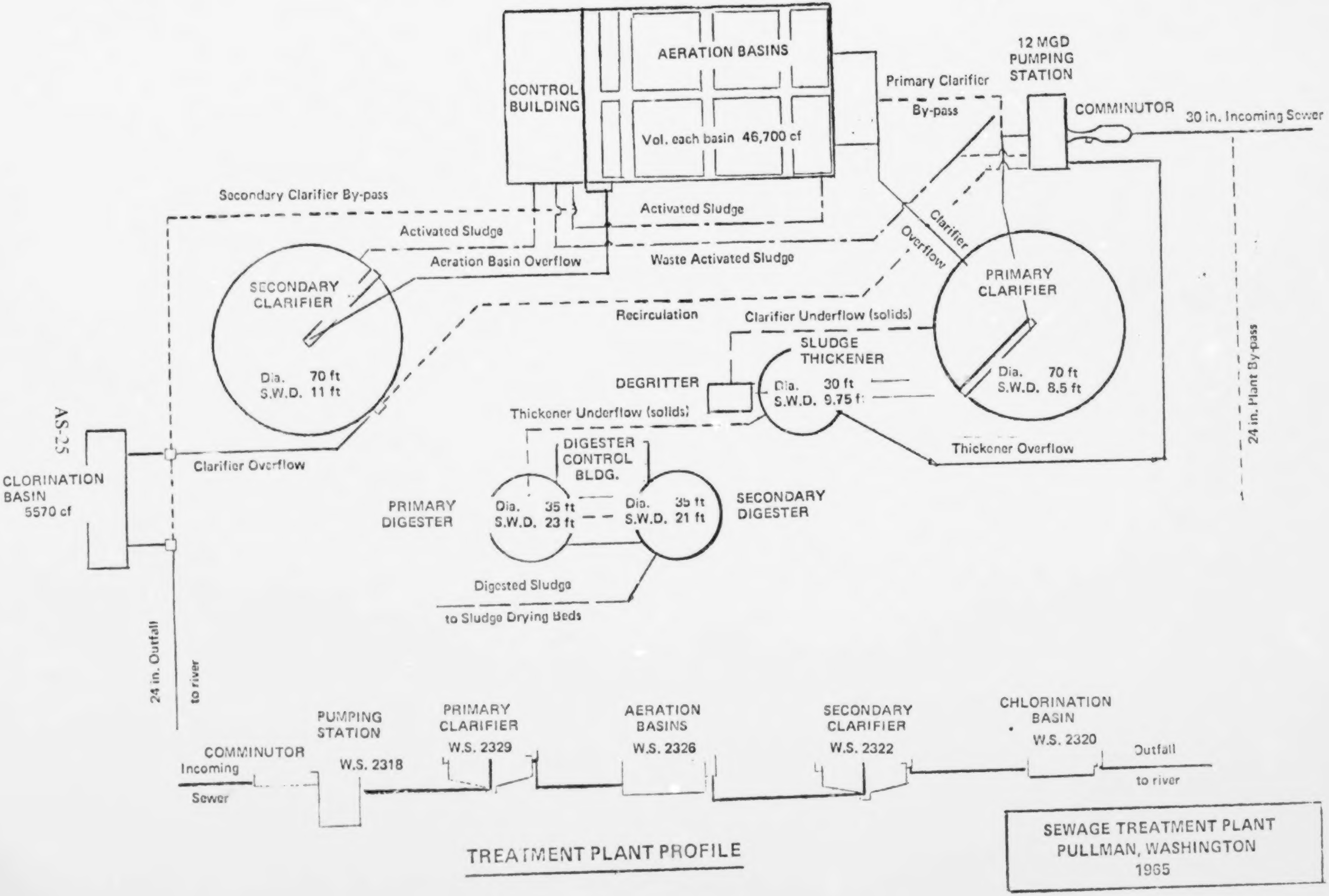
This City of Pullman facility is operated by the Department of Public Works and treats the sewage from both the community and the Washington State University Campus. WSU contributes financially to the maintenance and operation of the plant.

The original plant was completed in 1949 at a cost of approximately $300,000. This plant was a bio-filtration type treatment plant.

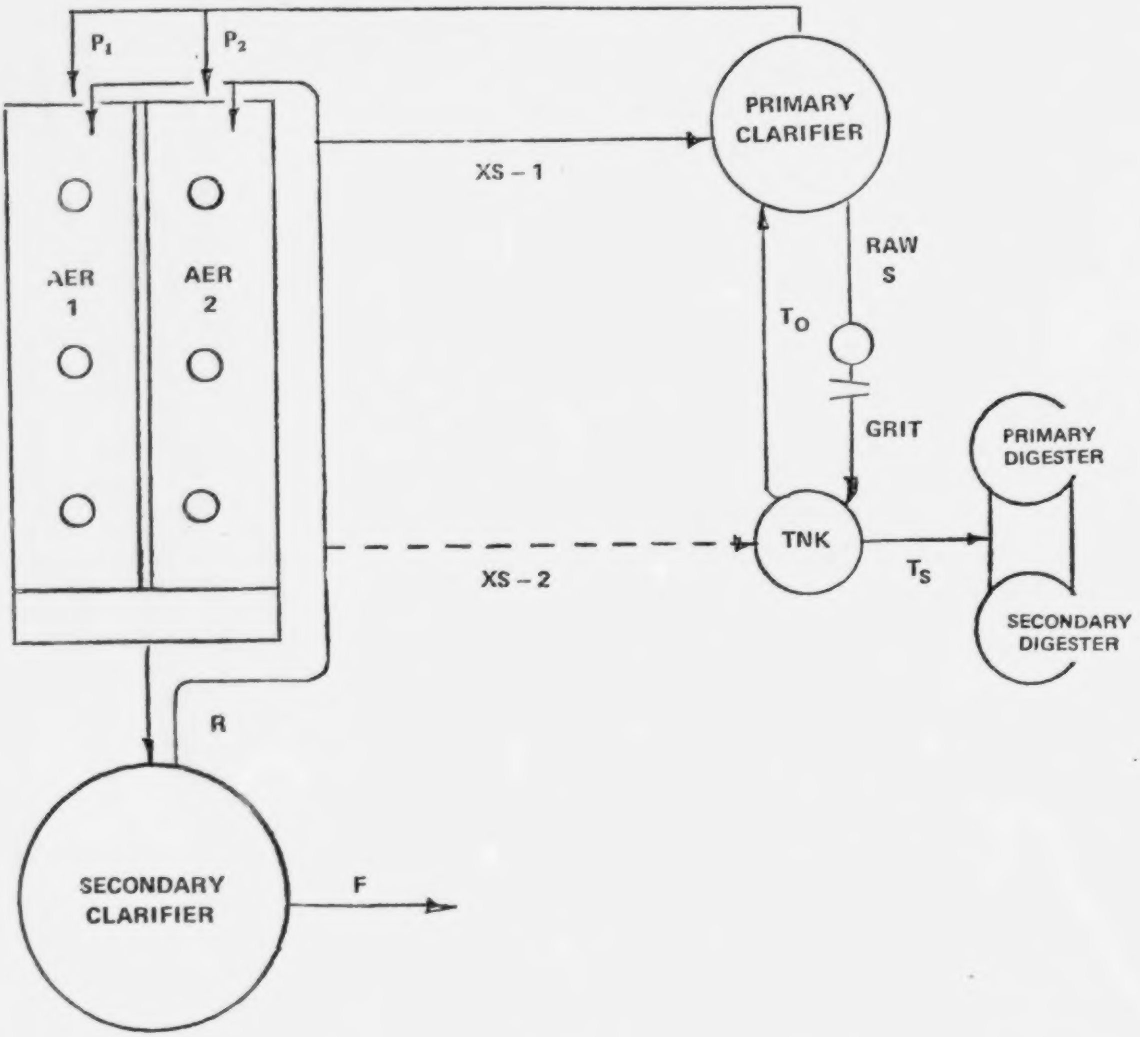
Due to the increased use of water by the population, it became necessary to increase the capacity of the plant. To accomplish this, the plant was remodeled in 1965. At that time it was changed to an activated sludge type plant to more effectively treat both the low quantity of sewage received during the summer months and the high quantities received during the winter months with the return of the students to WSU. The remodeling cost was approximately $500,000.

Operational History

1. Plant is at maximum hydraulic capacity during wet weather in excess of 4.0 MGD
2. Student population from WSU affects plant loading
3. It is hard to stabilize the plant operation during and after student vacations, particularly Thanksgiving and Christmas
4. The plant has a weak sewage averaging between 80 and 120 BOD
5. Characteristically the plant has carried a low MLSS
6. Aeration tanks have three sparge-turbine type aerators in each tank
7. The aerators have a hydrogen sulfide odor when the DO drops near 0
8. No digester supernatant is returned to the system, all of it is hauled and disposed of on land
9. Waste sludge is typically wasted back to the primary clarifiers


AERATION BASINS
Vol. each basin 46,700 cf
CONTROL BUILDING
12 MGD PUMPING STATION
COMMINUTOR
30 in. Incoming Sewer
24 in. Plant By-pass
Primary Clarifier By-pass
Clarifier Overflow
PRIMARY CLARIFIER
Dia. 70 ft
S.W.D. 8.5 ft
Secondary Clarifier By-pass
Activated Sludge
Activated Sludge
Aeration Basin Overflow
Waste Activated Sludge
SECONDARY CLARIFIER
Dia. 70 ft
S.W.D. 11 ft
Recirculation
Clarifier Underflow (solids)
SLUDGE THICKENER
Dia. 30 ft
S.W.D. 9.75 ft
DEGRITTER
Thickener Underflow (solids)
Thickener Overflow
DIGESTER CONTROL BLDG.
PRIMARY DIGESTER
Dia. 35 ft
S.W.D. 23 ft
SECONDARY DIGESTER
Dia. 35 ft
S.W.D. 21 ft
Digested Sludge
to Sludge Drying Beds
Clarifier Overflow
CLORINATION BASIN 5570 cf
24 in. Outfall
to river
Incoming Sewer
COMMINUTOR
PUMPING STATION
W.S. 2318
PRIMARY CLARIFIER
W.S. 2329
AERATION BASINS
W.S. 2326
SECONDARY CLARIFIER
W.S. 2322
CHLORINATION BASIN
W.S. 2320
Outfall
to river
TREATMENT PLANT PROFILE

SEWAGE TREATMENT PLANT
PULLMAN, WASHINGTON
1965


P$_1$
P$_2$
PRIMARY CLARIFIER
XS – 1
AER 1
AER 2
RAW S
T$_O$
GRIT
PRIMARY DIGESTER
TNK
XS – 2
T$_S$
SECONDARY DIGESTER
R
SECONDARY CLARIFIER
F

SIMPLIFIED FLOW PATTERN,
PULLMAN TREATMENT PLANT

PULLMAN, WASHINGTON – FACTS ABOUT THE PLANT

Design Flow:

Minimum Daily Flow	2.80 Million Gallons per day
Average Daily Flow	4.00 Million Gallons per day
Maximum Daily Flow	6.50 Million Gallons per day
Maximum Hydraulic Flow	12.00 Million Gallons per day

Strength of Sewage:

	Suspended Solids	BOD
Minimum	140 ppm	120 ppm
Average	225 ppm	210 ppm
Maximum	270 ppm	250 ppm

Pump Station:

Five Raw Sewage Pumps

2 rated 1,000 gpm @ 13' of head each

3 rated 2,100 gpm @ 13' of head each

Volume, wet pit at overflow: 8,950 gallons

Primary Clarifier:

Diameter: 70'

Side wall depth: 8.5' Volume: 246,000 gallons

Aeration Basins:

Two Basins: Volume of each: 350,000 gallons

Blower Capacity: 3 blowers, each @ 600 cfm

Activated Sludge Pumps: 2 pumps, each @ 1,600 gpm @ 35' of head

Secondary Clarifier:

Diameter: 70'

Side wall depth: 11'

Chlorine Retention Basin:

1 Basin Retention time: 20 min. minimum

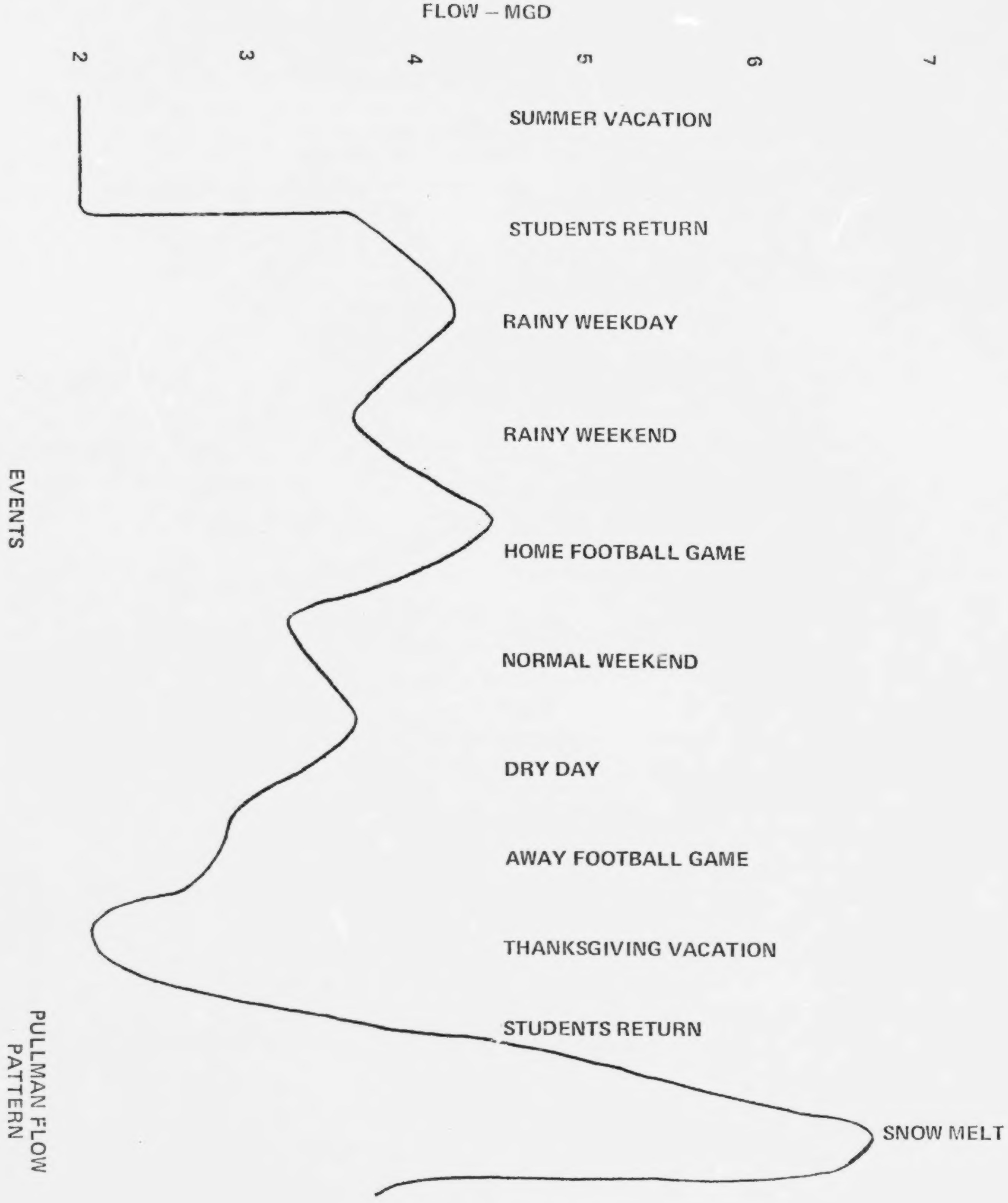
Sludge Thickener:

Diameter: 70'

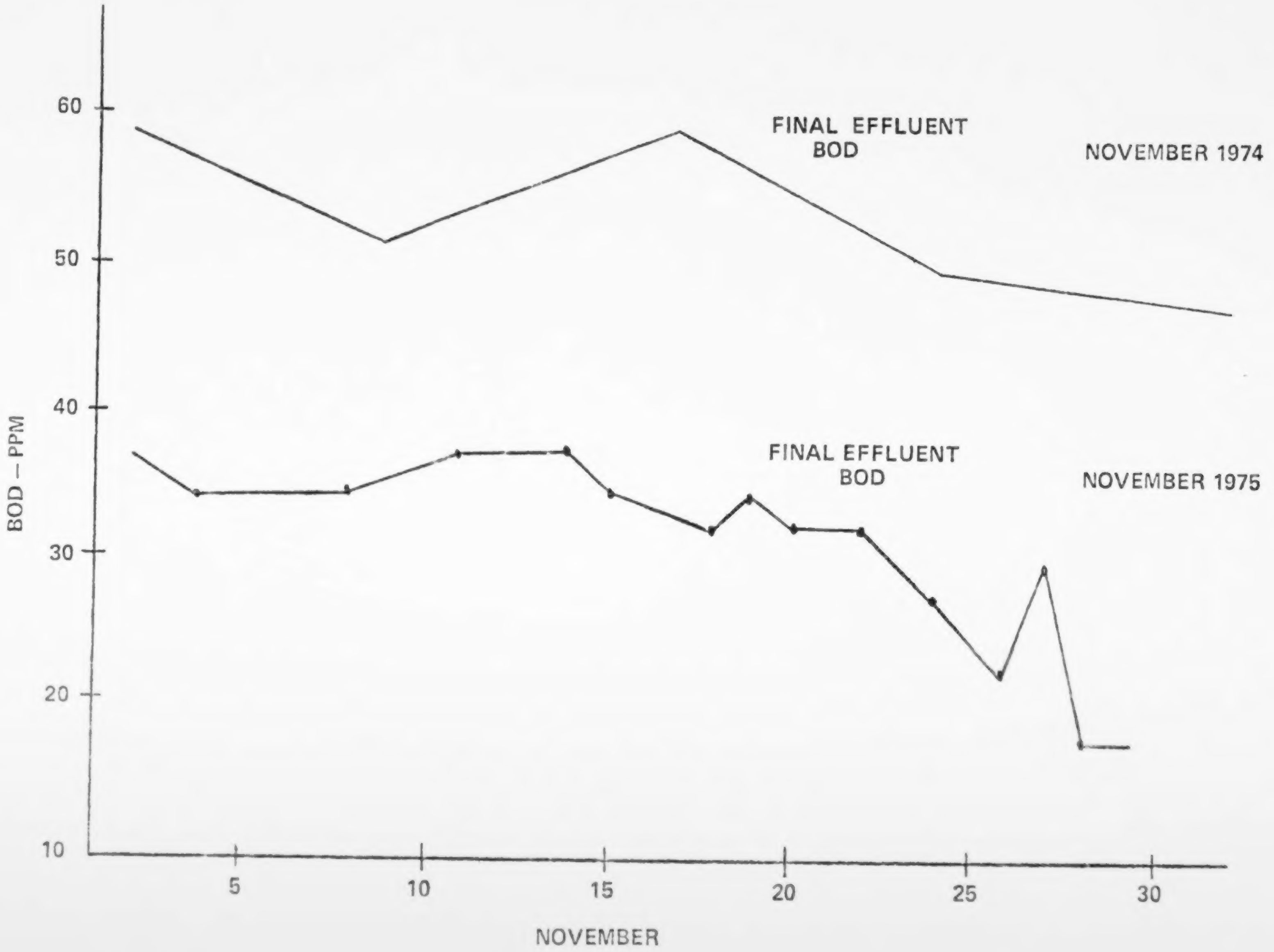
Side wall depth: 10' Volume: 53,000 gallons

Sludge Digesters:

Primary:	Diameter:	35'	Volume: 176,200 gallons
	Side wall depth:	23'	
Secondary:	Diameter:	35'	Volume 161,200 gallons
	Side wall depth:	21'	
			Total Volume: 337,400 gallons



PULLMAN FLOW PATTERN



PULLMAN – BOD REMOVAL

ACTIVATED SLUDGE – SUBDIVISION 6

Pullman Troubleshooting Problem – Answer Sheet

Student Group____________

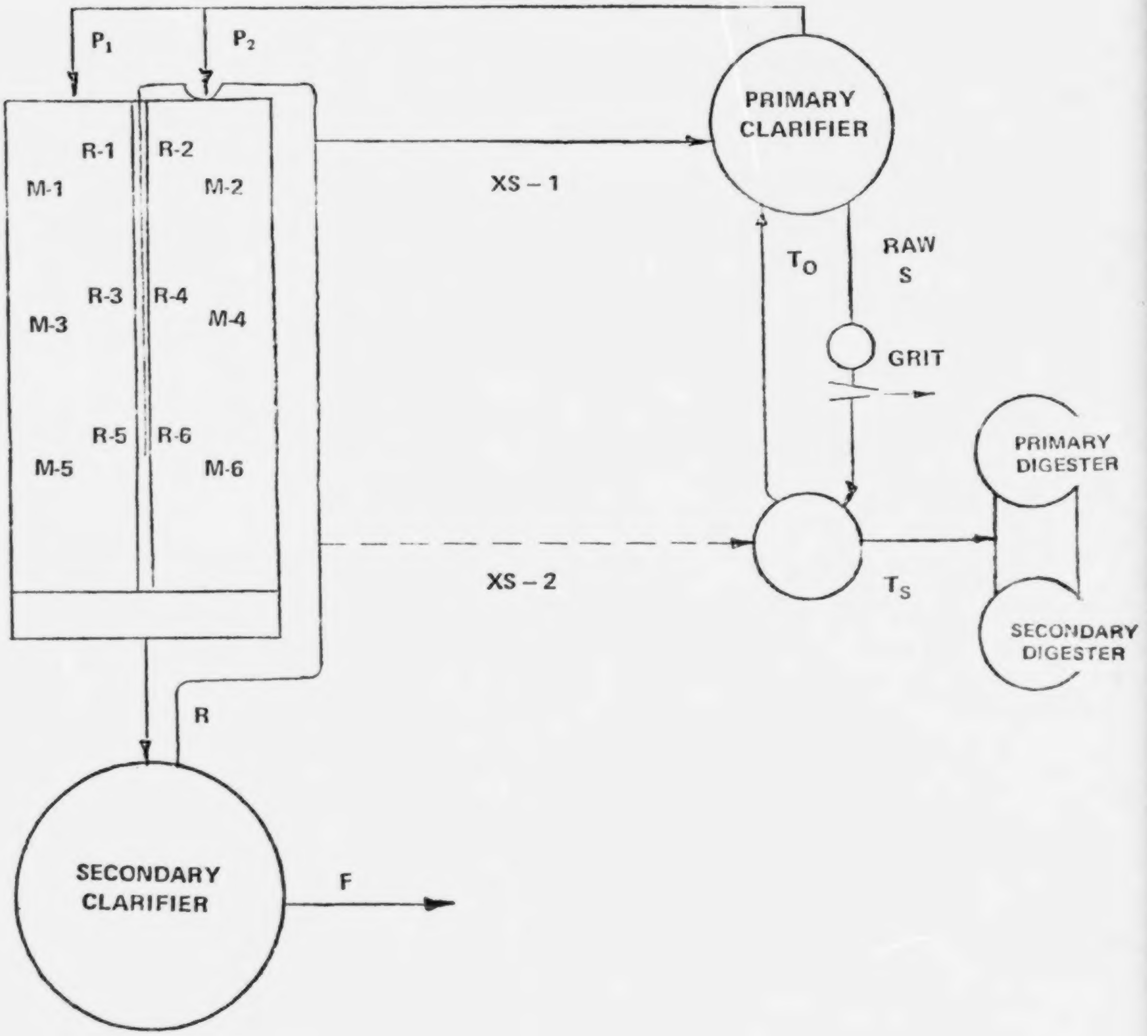
1. Briefly describe and define the problem that existed at Pullman in 1974.

2. Using the Process of Troubleshooting, describe
   a. The data you would need
   b. The analysis you would make

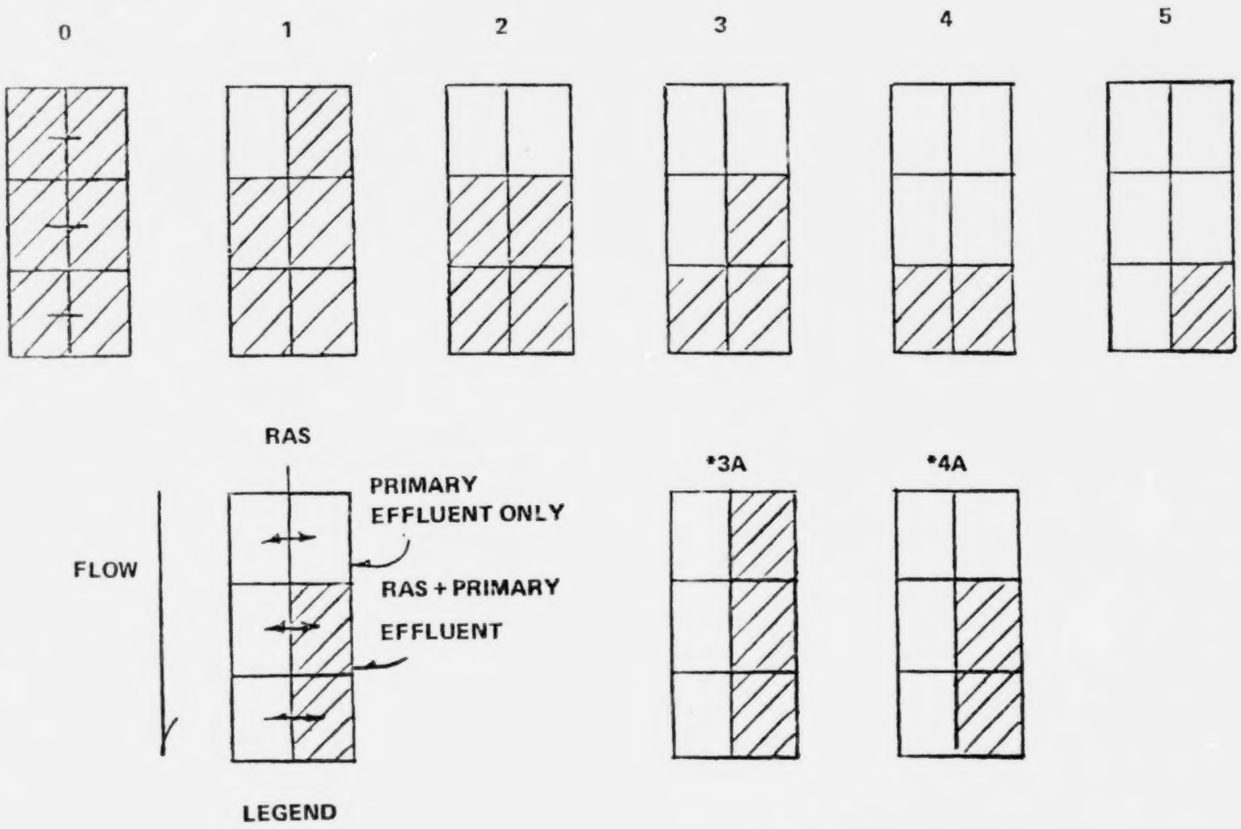
3. What process changes would you recommend to cope with the fluctuating load? What other changes?

4. What process control strategy would you use to control the activated sludge process? How would you do it?

PULLMAN – MODIFIED RETURN ACTIVATED SLUDGE


P_1
P_2
R-1
R-2
M-1
M-2
R-3
R-4
M-3
M-4
R-5
R-6
M-5
M-6
XS – 1
XS – 2
PRIMARY CLARIFIER
T_O
RAW S
GRIT
PRIMARY DIGESTER
SECONDARY DIGESTER
T_S
R
SECONDARY CLARIFIER
F

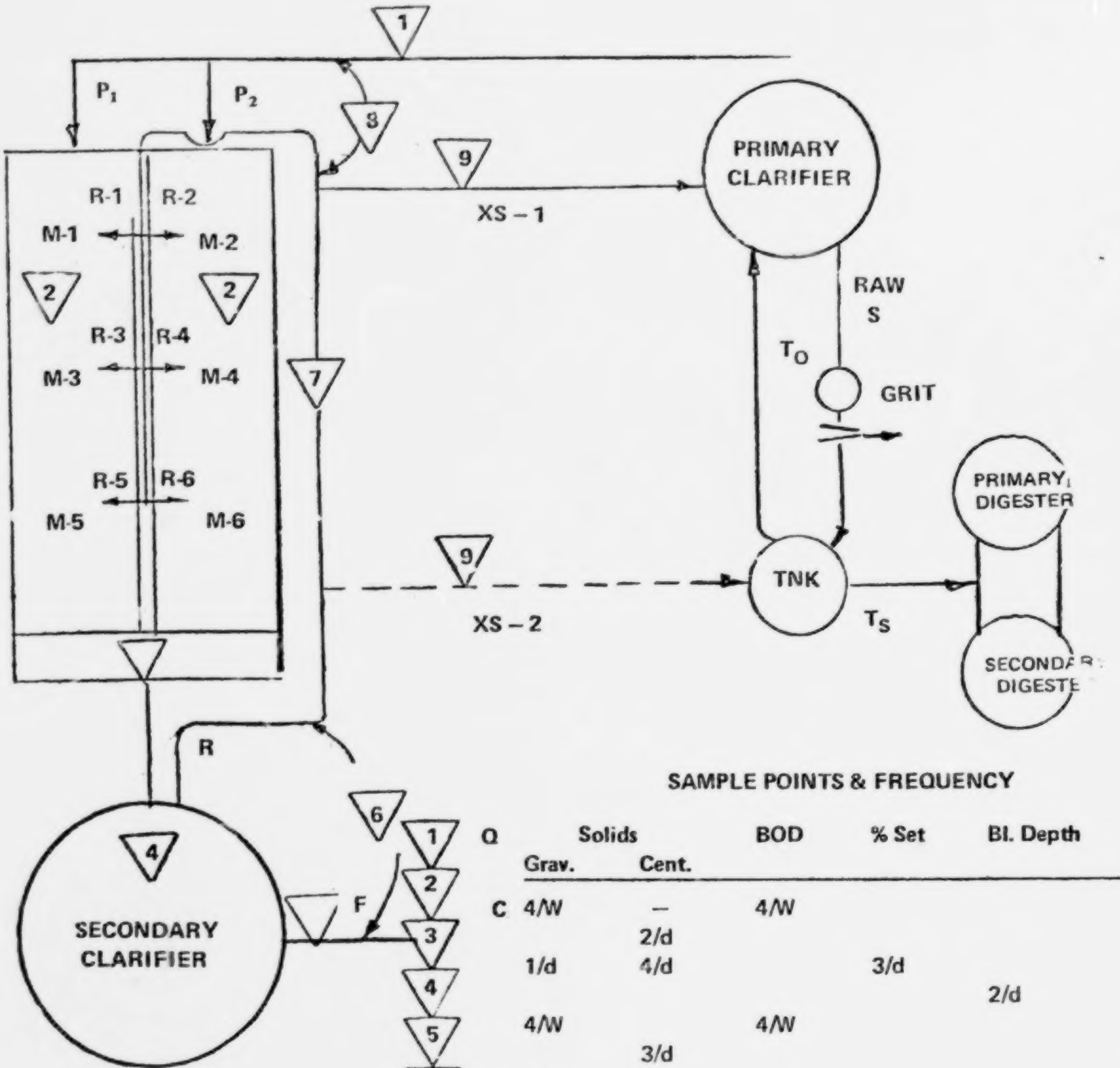
P-n	Primary Effluent
M-n	Mixed Liquor
R-n	Return Sludge
F	Final Effluent
XS-n	Waste Sludge
T_S	Thickened Sludge
T_O	Thickener Overflow


0
1
2
3
4
5
RAS
FLOW
PRIMARY EFFLUENT ONLY
RAS + PRIMARY EFFLUENT
LEGEND
*3A
*4A

*For use when only one aerator is in use.

PULLMAN – AERATOR MODES

PULLMAN – SAMPLING SCHEME

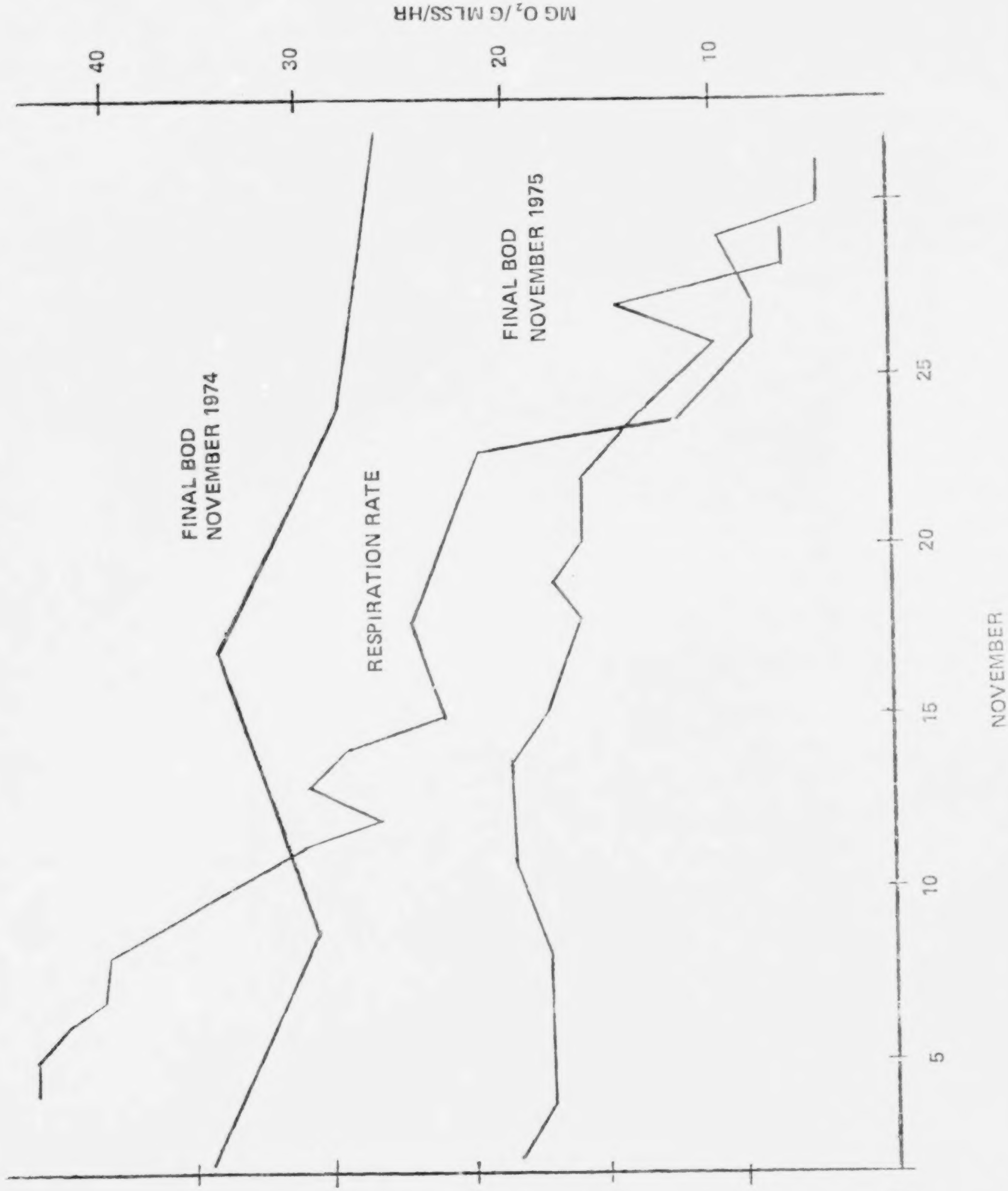

1
P1
P2
8
9
XS – 1
PRIMARY CLARIFIER
R-1
R-2
M-1
M-2
2
2
R-3
R-4
M-3
M-4
7
RAW S
TO
GRIT
R-5
R-6
M-5
M-6
PRIMARY DIGESTER
9
XS – 2
TNK
TS
SECONDA DIGESTE
R
6
4
SECONDARY CLARIFIER
F

SAMPLE POINTS & FREQUENCY

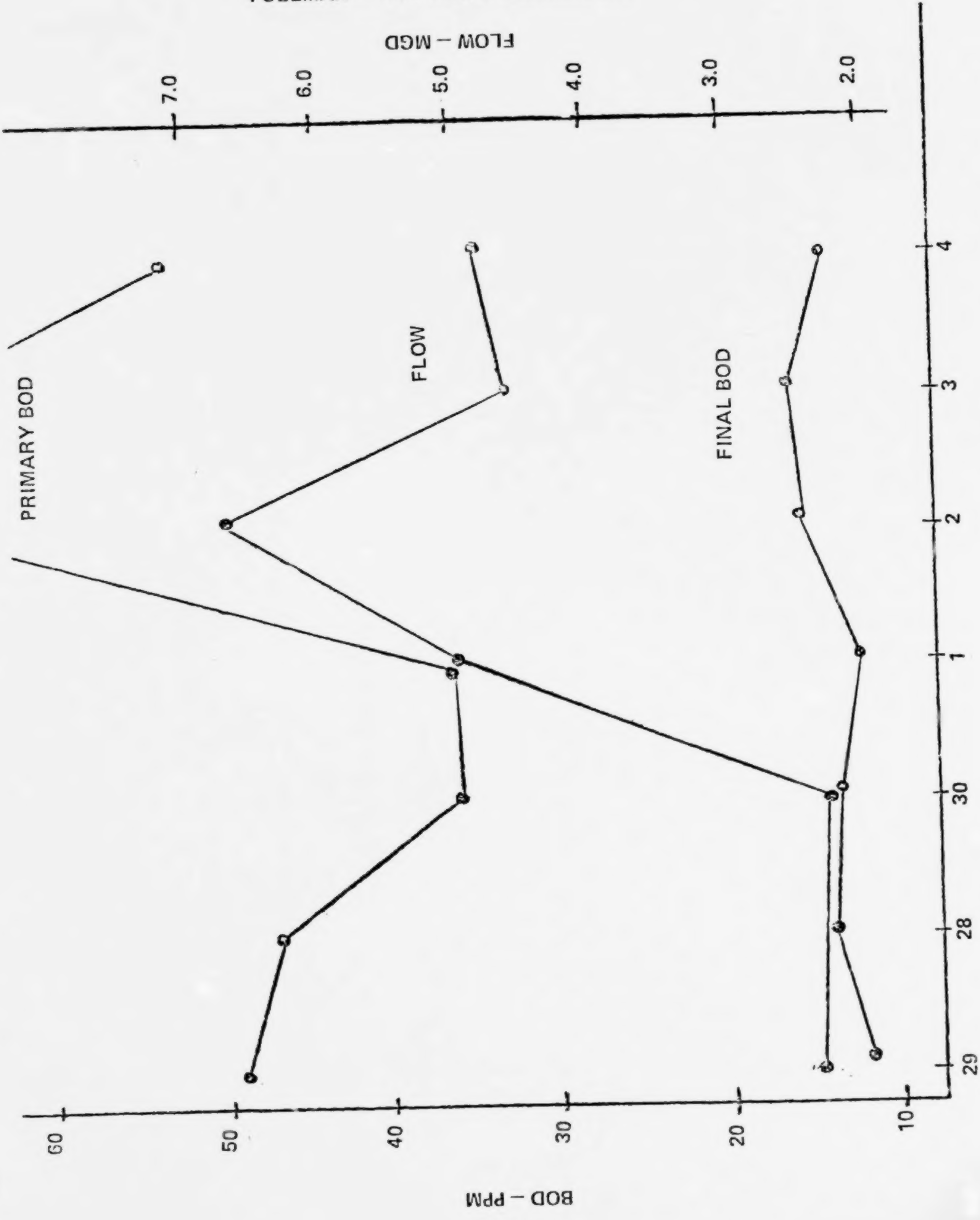
	Q	Solids		BOD	% Set	Bl. Depth	Resp. Rate
		Grav.	Cent.				
1	C	4/W	–	4/W			
2			2/d				
3		1/d	4/d		3/d		3/d
4						2/d	
5		4/W		4/W			
6			3/d				3/d
7	C	1/d	4/d				
8			3/d				3/d
9	C	1/d	3/d				

P-n	Primary Effluent
M-n	Mixed Liquor
R-n	Return Sludge
F	Final Effluent
XS-n	Waste Sludge
T_S	Thickened Sludge
T_O	Thickener Overflow

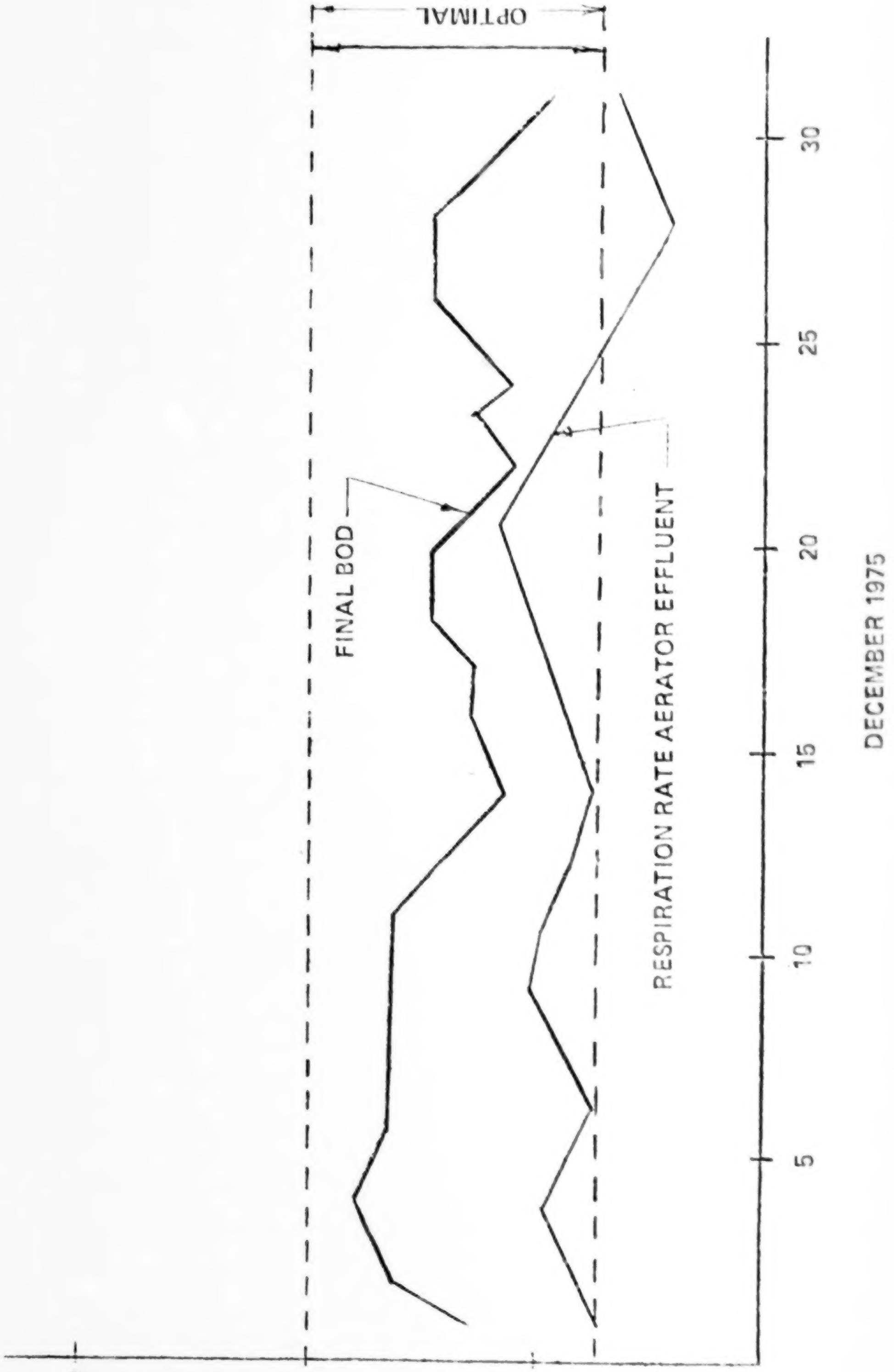
PULLMAN – NOVEMBER 1975 RESULTS



PULLMAN – 1975 VACATION RESULTS



PULLMAN – FINAL RESULTS
DECEMBER 1975



AS-36

SPRING AND SUMMER STUDIES
FOUR EXTENDED AERATION PACKAGE SEWAGE TREATMENT PLANTS
SUBDIVISION FLOW PATTERN

(mean values)

	ITEM	INFLUENT	EFFLUENT	
			FULL LOAD	HALF LOAD
1.	BOD_5 (mg/l)	198.0	20.0	10.0
2.	SS (mg/l)	234.0	36.0	32.0
3.	VS (mg/l	192.0	26.0	22.0
4.	COD (mg/l)	220.0	32.0	18.0
5.	% Volatile	82.0	72.0	69.0
6.	pH	7.5	7.1	7.2
7.	Alkalinity (mg/l)	48.0	19.5	14.2
8.	$NH_3 - N$ (mg/l)	17.4	0.0	0.0
9.	$NO_3 - N$ (mg/l)		15.3	20.0
10.	$PO_4 - P$ (Total Soluble) (mg/l)	11.3	11.3	10.3
11.	Dissolved Oxygen (mg/l)		1.6	2.2
12.	M.B.A.S. (mg/l)	6.1	0.8	0.9
13.	BOD/SS	0.85	0.56	0.31
14.	BOD/VS	1.03	0.77	0.45
15.	BOD/COD	0.90	0.63	0.56
16.	% Reduction			
	a. BOD_5		90.0	95.0
	b. SS		85.0	86.0
	c. VS		86.0	89.0
	d. COD		85.0	92.0
	e. Alkalinity		59.0	71.0
	f. $NH_3 - N$		100.0	100.0
	g. PO_4 P		0.0	8.8
	h. M.B.A.S.		87.0	85.0
			Mixed Liquor	
			Full Load	Half Load
17.	MLSS (mg/l)		4,330.0	3,050.0
18.	MLVSS (mg/l)		3,120.0	2,130.0
19.	% Volatile		72.0	70.0
20.	pH		7.3	6.9
21.	SV_{30} (ml)		650.0	285.0
22.	Sludge Density Index		0.67	1.07
23.	Temperature (^{0}C)		18.6	18.2
24.	Dissolved Oxygen (mg/l)		2.0	3.0
25.	lb BOD_5/lb MLSS		0.05	0.03
26.	lb BOD_5/lb MLVSS		0.06	0.05

WINTER AND SPRING STUDIES*
CONTACT STABILIZATION PACKAGE SEWAGE TREATMENT PLANTS
FULL DESIGN LOADING – VARIABLE FLOW PATTERN

	INFLUENT				EFFLUENT				
Item	No. of Samples	Min.	Max.	Mean	No. of Samples	Min.	Max.	Mean	Percent Removal
BOD_5 (mg/l)	248	112.0	305.0	184.0	236	6.0	236.0	46.0	75.0
SS (mg/l)	252	98.0	282.0	171.0	251	0.0	238.0	24.0	86.0
VSS (mg/l)	248	88.0	234.0	145.0	248	0.0	198.0	19.0	86.9
COD (mg/l)	244	164.0	652.0	369.0	241	20.0	272.0	74.0	79.9
NH_3 – (mg/l)	124	10.0	25.0	18.5	124	1.0	20.0	10.6	–
NH_3 – N (mg/l)	128	–	–	***	128	0.2	20.2	4.5	–
PO_4 P (mg/l)	120	22.0	72.0	37.2	120	12.0	40.8	26.5	28.8

MIXED LIQUOR AND STABILIZATION COMPARTMENT SOLIDS

Item	No. of Samples	Min.	Max.	Mean	Percent Volatile
MLSS (mg/l)	252	660	5,260	1,942	79.9
MLVSS (mg/l)	249	420	4,530	1,552	
SV_{30} (ml)	248	50	850	343	
SVI	248	41	495	177	
SCSS (mg/l)	246	600	8,010	2,924	80.4**
SCVSS (mg/l)	125	850	6,640	2,492	
RSSS (mg/l)	540	1,000	8,400	3,485	81.6**
RSVSS (mg/l)	43	1,170	6,400	3,332	

* These data were collected during the period of criteria development and are not the result of testing under the conditions established for certification testing.

** Calculated from paired samples only.

*** The mean NO_3 – N in the influent for this series of data was 0.2 mg/l.

SPRING AND SUMMER STUDIES *
CONTACT STABILIZATION PACKAGE SEWAGE TREATMENT PLANTS
FULL DESIGN LOADING – VARIABLE FLOW PATTERN

	INFLUENT				EFFLUENT				
Item	No. of Samples	Min.	Max.	Mean	No. of Samples	Min.	Max.	Mean	Percent Removal
BOD$_5$ (mg/l)	87	100.0	297.0	167.0	86	1.0	220.0	37.0	77.8
SS (mg/l)	88	126.0	344.0	184.0	88	3.0	318.0	45.0	75.5
VSS (mg/l)	88	70.0	278.0	149.0	88	0.0	218.0	35.0	76.5
MBAS (mg/l)	83	1.9	10.0	5.6	83	0.0	2.4	0.6	89.3
COD (mg/l)	88	140.0	676.0	368.0	88	16.0	392.0	89.0	75.8
NH$_3$ – N (mg/l)	88	6.0	22.1	17.1	88	3.3	22.1	10.7	–
NO$_3$ – N (mg/l)	88	–	–	**	88	0.3	16.0	3.5	–
PO$_4$ – P (mg/l)	87	21.0	80.0	52.9	87	23.2	53.6	36.3	31.4

MIXED LIQUOR AND STABILIZATION COMPARTMENT SOLIDS

Item	No. of Samples	Min.	Max.	Mean	Percent Volatile
MLSS (mg/l)	91	1,300	6,650	3,406	
MLVSS (mg/l)	91	970	4,550	2,561	75.2
SV$_{30}$ (ml)	91	90	950	531	
SVI	91	39	486	156	
SCSS (mg/l)	68	2,970	8,460	5,572	
SCVSS (mg/l)	68	2,270	6,840	4,264	76.5
RSSS (mg/l)	91	1,110	11,580	6,935	
RSVSS (mg/l)	91	740	8,830	5,062	73.0

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* These data were collected during the period of criteria development and are not the result of testing under the conditions established for certification testing.

** The mean NO$_3$ – N in the influent for this series of data was 0.4 mg/l.

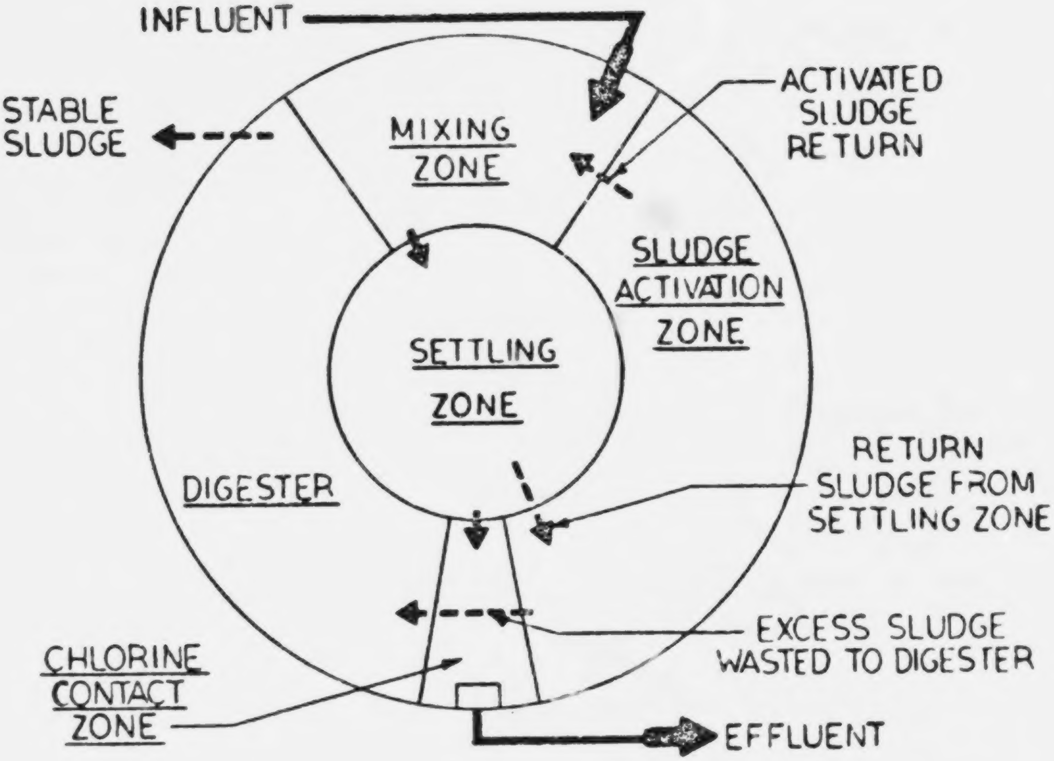
TROUBLESHOOTING GUIDE – EXTENDED AERATION PLANTS

CASE NO.	AERATION TANK SAMPLE JAR CONDITIONS	PLANT EFFLUENT SAMPLE JAR CONDITIONS	INTERPRETATION	CONFIRMATORY PLANT CONDITION OBSERVATIONS	ACTION REQUIRED
I	Heavy, rapid settling, brown sludge occupying 10 – 70% of the jar volume. Clear liquid above sludge. Faint musty, earthy odor.	Light dusting of fine pinpoint solids on bottom. Clear liquid above. Faint musty odor.	Plant in good operating condition	No objectionable odors. Clear effluent. No black or brown sludge floating on surface of settling tank.	None
II	Same as Case I.	Relatively large volume of sludge on bottom of jar – 1/8 in. or more thick. Faint musty odor.	Excessive loss of solids because of too high a flow rate through settling basin.	Flow into plant abnormally high. Indicated by measuring weir or depth of flow in inlet or outlet sewer.	Check sewer system for stormwater infiltration or unusual water discharges. If lift station precedes plant, reduce discharge rate.
III	Very heavy but good settling brown sludge occupying 70% of jar volume or more. Unobjectionable musty odor.	Very large volume of brown sludge on bottom of jar. Musty odor.	Excessive loss of solids because of too high a solids concentration in aeration tank.	Heavy solids concentration in settling basin for entire depth and solids discharging over effluent trough weirs.	Remove solids from system by pumping to tank truck and hauling to farm land or dump.
IV	Poor separation of solids from liquid. Little clear liquid. Brown fluffy sludge hangs in liquid or floats on water surface. Faint musty, earthy odor.	Relatively little settling of solids. Fluffy solids in suspension in liquid and floating at surface. Faint musty odor. Little clear liquid.	Denitrification in settling basin releases nitrogen gas causing sludge to float.	No objectionable odor in aeration tank. Blanket of brown sludge over surface of settling basin which will gradually turn septic if not removed.	Reduce air supply. Increase rate of returning sludge to aeration tank if possible to reduce settling basin retention time.
V	Heavy, rapid settling, dark brown or dark gray to black sludge occupying 15 – 70% of jar volume. Cloudy or turbid liquid above sludge. Musty or faint septic (sour) sewage odor.	Relatively more solids than in Case I. Bottom of jar covered with distinct layer of sludge. Liquid cloudy to turbid. Noticeably septic odor.	Deficiency in animal predators (protozoa) to feed on bacteria, probably caused by too little air but possibly by abnormal pH (acidity or alkalinity), if septic conditions are not present.	Aeration tank contents abnormally dark with possible septic odor. Cloudy effluent with possible septic odor.	Increase air supply. Check pH if septic conditions are not present. Add lime or soda ash if pH is below 6.0. Add acid if pH is above 9.0. Check for industrial wastes. Eliminate if found.
VI	Very heavy, fair settling, dark gray or black sludge occupying 50% of jar volume or more. Septic odor.	Same as Case III, except sludge is dark gray or black instead of brown.	Too little air for heavy solids load and excessive loss of solids in plant effluent because of too high a solids load in aeration tank.	Same as Case III except solids are dark gray or black instead of brown.	Increase air supply if possible and waste solids as in Case II. Check for overload and add treatment capacity if needed.

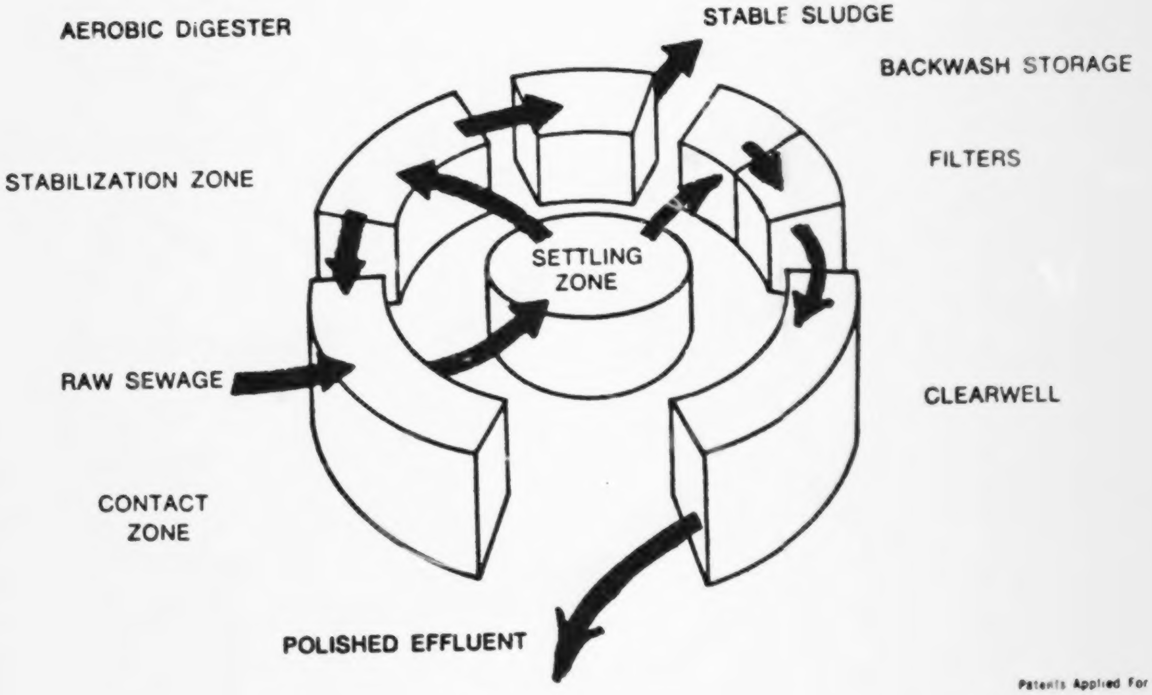
SMALL PACKAGE PLANT DAILY CHECKLIST*

1. Clean bar screen and pick up sample for raw settleable solids test
2. Notice conditions of floc
3. Notice conditions of aeration chamber
4. Notice conditions of sludge return
5. Check for foam on aeration chamber
6. Final Clarifier:
    a. Check surface skimmer
    b. Check appearance of clarifier liquid
    c. Clean weir troughs
    d. Squeegee solids
    e. Check level of sludge blanket
    f. Remove any leaves, etc from surface
    g. Pick up sample for final effluent settleable solids test
    h. Check chlorine residual
7. Air Compressors:
    a. Visually inspect motors
    b. Listen for any unusual noises
    c. Rotate motors and change compressors
    d. Inspect motors for overheating
    e. Check oil levels
    f. Grease motors if needed
    (Motors should be greased as specified by the manufacturers. Normally, when manufacturing information is not available, two small shots of grease every 6 months is sufficient)
    g. Inspect Hypochlorinator:
        1. Determine HTH level
        2. Check discharge line

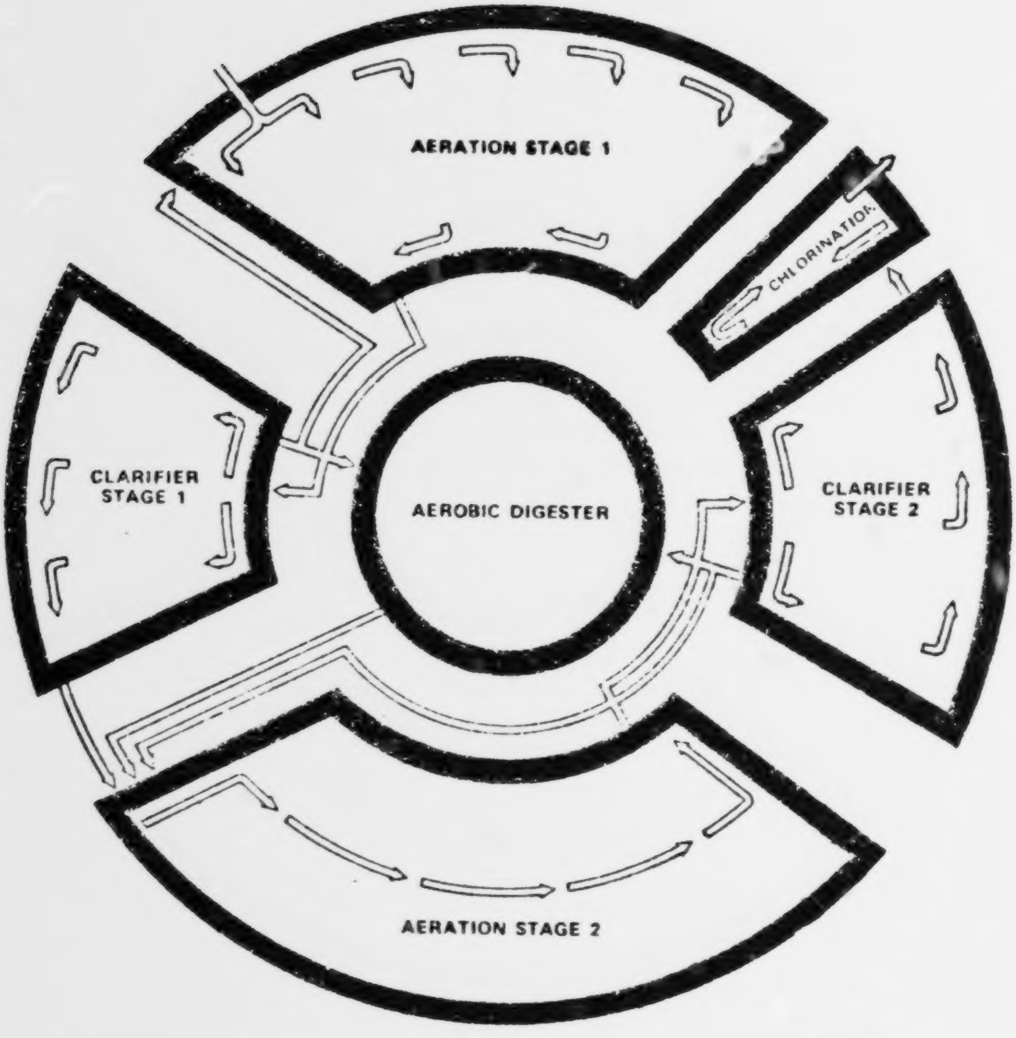
* Provided by the Texas Water Quality Board


INFLUENT
STABLE SLUDGE
MIXING ZONE
ACTIVATED SLUDGE RETURN
SLUDGE ACTIVATION ZONE
SETTLING ZONE
DIGESTER
RETURN SLUDGE FROM SETTLING ZONE
EXCESS SLUDGE WASTED TO DIGESTER
CHLORINE CONTACT ZONE
EFFLUENT

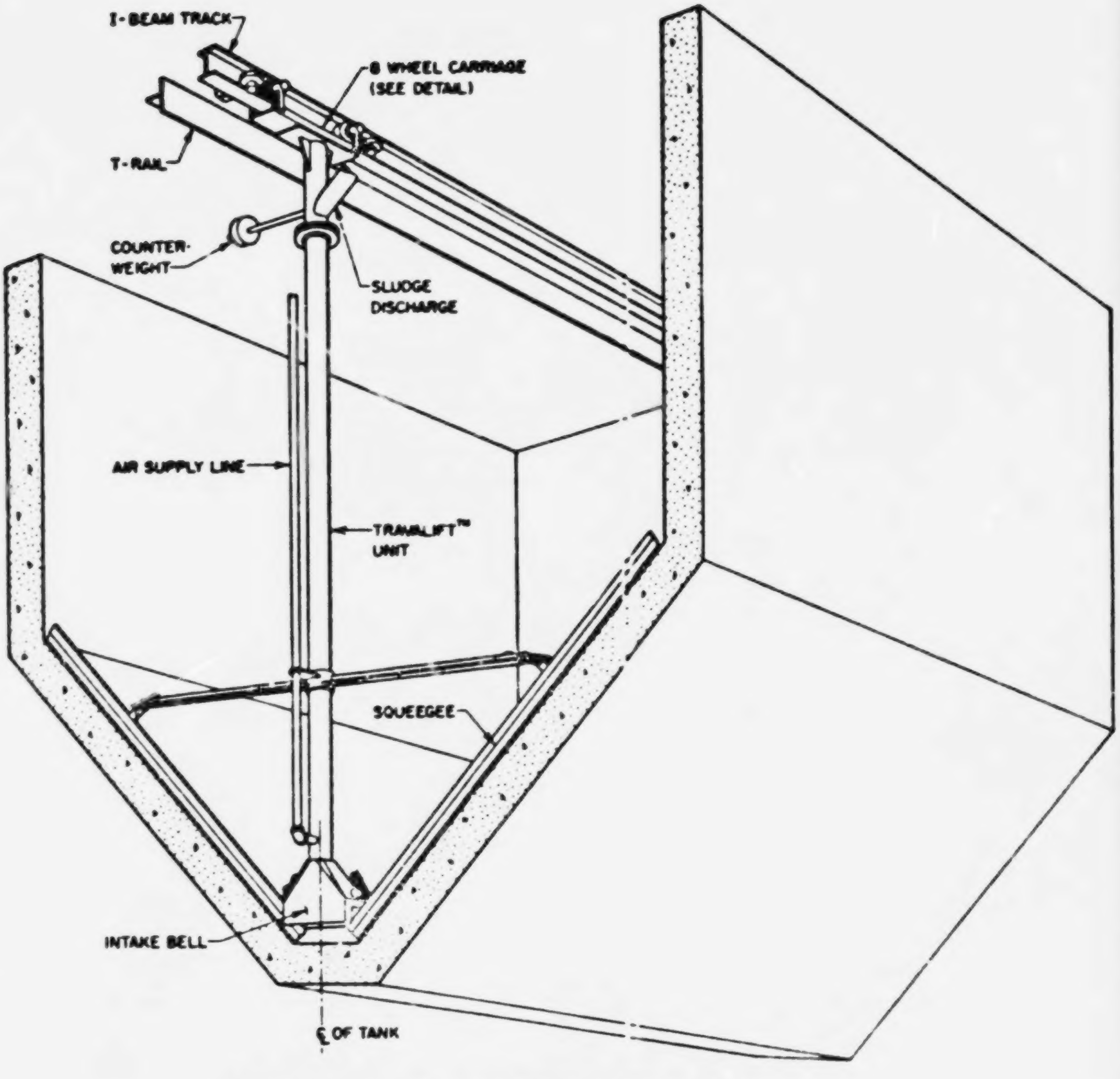
Flow Diagram - Contact Stabilization
Package Treatment Plant


AEROBIC DIGESTER
STABLE SLUDGE
BACKWASH STORAGE
FILTERS
STABILIZATION ZONE
SETTLING ZONE
RAW SEWAGE
CLEARWELL
CONTACT ZONE
POLISHED EFFLUENT
Patents Applied For

Flow Diagram - Circular Plant With Tertiary Treatment

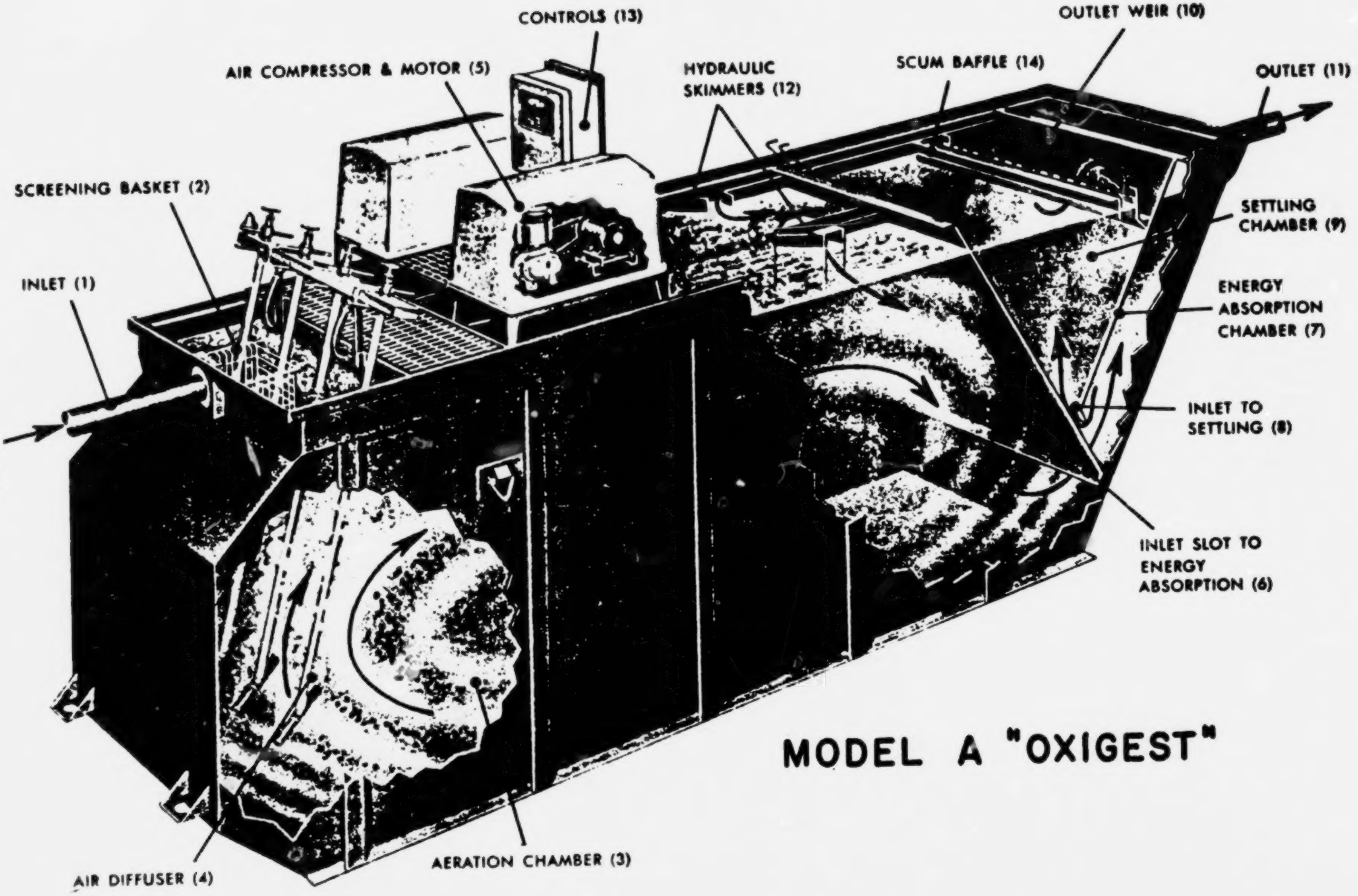

AERATION STAGE 1
CHLORINATION
CLARIFIER STAGE 1
AEROBIC DIGESTER
CLARIFIER STAGE 2
AERATION STAGE 2

Flow Diagram - Alternative Circular Configuration


I-BEAM TRACK
8 WHEEL CARRIAGE (SEE DETAIL)
T-RAIL
COUNTER-WEIGHT
SLUDGE DISCHARGE
AIR SUPPLY LINE
TRAVALIFT™ UNIT
SQUEEGEE
INTAKE BELL
℄ OF TANK

TRAVALIFT INSTALLATION

Moving Suction System In A Rectangular Plant


CONTROLS (13)
OUTLET WEIR (10)
AIR COMPRESSOR & MOTOR (5)
HYDRAULIC SKIMMERS (12)
SCUM BAFFLE (14)
OUTLET (11)
SCREENING BASKET (2)
SETTLING CHAMBER (9)
INLET (1)
ENERGY ABSORPTION CHAMBER (7)
INLET TO SETTLING (8)
INLET SLOT TO ENERGY ABSORPTION (6)
MODEL A "OXIGEST"
AIR DIFFUSER (4)
AERATION CHAMBER (3)

Rectangular Oxigester Plant

REFERENCES – ACTIVATED SLUDGE

National Waste Treatment Center. Operational Control Procedures for the Activated Sludge Process. Environmental Protection Agency, Cincinnati, Ohio.

Stevens, Thompson & Runyon, Inc. Operator's Pocket Guide to Activated Sludge, Pamphlets, Parts I & II. Portland, Oregon.

Jim Nemke. Visual Observations Can be Process Control Aids. Water Pollution Control Federation Deeds & Data, September 1975.

J. Edward Meers. Activated Sludge Process and Operation Control. In: The Digester, State of Illinois, May 1975.

W. D. Hatfield, Operation of the Activated Sludge Process. Journal, Water Pollution Control Federation, June, 1966.

Sherrard & Kincannon. Operational Control Concepts for the Activated Sludge Process. Water & Sewage Works, March, 1974.

LESSON – SOLIDS HANDLING

Instructor Overview of Lesson

Entry Level Behavior: Students will have had University training in Sanitary Engineering, waste treatment and/or related sciences or equivalent in experience and training. Some field experience in inspecting solids handling facilities, but none in operating waste treatment facilities.

As a prerequisite to this course, it is recommended that the student will be able to –

1. Identify treatment plant process units.
2. Describe treatment plant process units and equipment in technical terms.
3. Identify and explain the purpose of components of treatment plant process units, how they work and why they are important to the overall process.
4. Describe the normal operating procedures for treatment plant process unit components.
5. Identify when treatment plant process units are not operating properly.

Instructor Objectives: The principal instructor objectives for this lesson are:

1. To stress the use of the Process of Troubleshooting as a tool to investigate operational problems in anaerobic digesters.
2. To utilize "role playing" and "fishbowl" techniques in confronting students with realistic troubleshooting problems.
3. To present the basic elements and approaches to troubleshooting for 6 solids handling processes.
4. To involve students in discussing a variety of solids handling problems that they have encountered.
5. To provide an actual case study of a problem in solids handling that affects total treatment plant performance.

References: Note list of references included with Student notebook materials.

Total Length of Lesson: 5 Subdivisions, 5 Hours, 40 Minutes.

LESSON OVERVIEW

Subdivision Title & Time	Major Student Objectives	Key Points & Contents	Approach	Materials
1. Anaerobic Digestion	1. Describe anaerobic digestion in understandable terms	1. Importance of solids handling, and solids handling problems	1. Instructor to follow lesson outline	1. Student Notebook, pages SH-1 thru SH-4
1 Hour	2. Identify and sketch various types of digesters	2. Communication problems between engineers and operators	2. Use of slide series and slide key	2. Slide series and key, 15 picture slides, 7 word slides
	3. Identify process parameters to measure	3. Significant process parameters in anaerobic digestion	3. Stimulation of student discussion by instructor	3. Process of Troubleshooting Chart
	4. List operating problems and approaches to investigating and correcting such problems	4. Troubleshooting anaerobic digestion problems		4. EPA Manual, "Evaluating the Performance of Wastewater Treatment Plants"
2. Problem Solving in Anaerobic Digestion – "Fishbowl" Technique	1. Employ the Process of Troubleshooting	1. Troubleshooting techniques	1. Role playing by student groups of troubleshooters	1. Instructions to troubleshooters, Problem 1
	2. Experience problems confronted by treatment plant operators	2. Relationships with operators	2. Observation of techniques by student reporters	2. Instructions to operating personnel, Problem 2
	3. Critique the troubleshooting techniques of others	3. Operator-troubleshooter behavior	3. Feedback on troubleshooting techniques given by student observers	3. EPA Manual, "Evaluating the Performance of Wastewater Treatment Plants"
110 Minutes	4. Have their troubleshooting techniques critiqued	4. Feedback on using troubleshooting techniques	4. Class discussion of results and experiences	

LESSON OVERVIEW (continued)

Subdivision Title & Time	Major Student Objectives	Key Points & Contents	Approach	Materials
3. Other Methods of Solids Handling	1. List and identify six unit processes of solids handling	1. Understanding normal process operations	1. Use lesson outline, with word slides as focal point of class discussion	1. Slide series and key, 24 word slides
90 Minutes	2. Describe normal operations and evaluation tests for each process	2. Evaluating process operations	2. Picture slide series on aerobic digestion	2. Slide series, 8 picture slides
	3. Identify operating problems, causes, and corrective actions for each process	3. Troubleshooting common operational problems	3. Frequent use of Notebook materials – process diagrams and troubleshooting guides	3. 9 Notebook pages – Process diagrams
			4. Delete processes not found in area where course is given	4. 6 Notebook pages – troubleshooting guide
				5. EPA Manual "Sludge Treatment and Disposal"
4. Tall Tales or "Where Did All That Sludge Come From?"	1. Identify actual solids handling problems and the approaches to solving them	1. Solids handling problems encountered in the region where the course is presented	1. Students provide actual problems, instructor screens and selects problems for discussion	1. No special materials required
40 Minutes	2. Recommend alternative approaches to solving problems		2. Selected problems are discussed by class	
5. Applying the Process of Troubleshooting	1. Analyze and troubleshoot a vacuum filtration problem	1. Case study – actual problem of plant failure due to improper solids handling	1. Instructor presents case study problem as the "operator"	1. Process of Troubleshooting Chart
40 Minutes	2. Discuss the connection between solids handling and overall treatment plant performance		2. Students "troubleshoot" the problem, advise on its solution	

LESSON – SOLIDS HANDLING

Presentation options for Course Director

The lesson on SOLIDS HANDLING is one of the major subject areas covered in this course. It contains five (5) subdivisions, and, as written, requires a presentation time of 5 hours, 40 minutes. This lesson could be expanded or shortened depending on the needs of the student group. However, in relation to a total course time of 28 to 40 hours, the existing time of presentation is appropriate. If the lesson needs to be significantly shortened for any reason, it is suggested that subdivision 5, and then subdivision 4 be reduced. However, the *minimum* time for presenting the significant points in this lesson is 4½ hours, reducing the lesson to subdivisions 1 through 3, with some additional discussion and a summary.

Some of the presentation options are as follows:

Subdivision 1 – Anaerobic Digestion: The existing 1 hour lesson is sufficient for students with the proper entry level background to the course. For students below that level, additional background material may have to be presented, and additional time would be required.

Subdivision 2 – Problem Solving in Anaerobic Digestion – "Fishbowl Technique:" This subdivision reinforces all of the emphasis on the Process of Troubleshoothing which is presented throughout the course. In effect, it is a test to see whether the students have acquired the skills and sensitivities which this course attempts to present. While it is possible to develop variations to the existing lesson material, this subdivision is an essential element to the course, and should be used as the course developers intended.

Subdivision 3 – Other Methods of Solids Handling: This subdivision covers some very important facets of solids handling. However, it is one of the more factual, "straightforward" lesson subdivisions.

One option for this subdivision would be to expand it by using slides which show all of the equipment which is described in the lesson. A second option, which could be valuable if time permits, would be to have the class visit a treatment plant that contains and uses the processes described. A third option would be to cover additional topics. This should be done only if a) other processes are common in the region where the course is held, and b) the time is broken up so that the presentation of this material is not continuous.

Finally, the Course Director should eliminate from this subdivision any solids handling process which is not common in the area where the course is being given.

Subdivision 4 – Tall Tales or "Where Did All That Sludge Come From?": This subdivision has proven to be very popular with students taking the course. It affords them an opportunity to discuss problems they have seen and experienced.

If the Solids Handling lesson must be reduced to below 5 hours, this subdivision may have to be reduced or deleted. However, it is recommended that it be kept intact and used as provided in the lesson plan materials.

Subdivision 5 – Applying the Process of Troubleshooting: This subdivision provides a useful summary to this very important lesson, and should be included if possible. However, if the lesson on solids handling needs to be shortened for any reason, this subdivision should be the first to be deleted.

SOLIDS HANDLING

LESSON PLAN – SUBDIVISION 1

TIME: 1 HOUR

Title: Anaerobic Digestion

Instructor Objectives: To introduce the overall subject of solids handling. To present the fundamentals of anaerobic digestion and to stress the use of the Process of Troubleshooting as a tool to investigate and solve operational problems in anaerobic digesters.

Student Objectives: As a result of this lesson subdivision, students will be able to do the following:

1. Describe the process of anaerobic digestion in terms that can be understood by plant operators.
2. Distinguish between various types of anaerobic digestion systems, and sketch simple process diagrams for each type.
3. Identify different types of anaerobic digesters while out in the field on inspection tours.
4. Identify process parameters to be monitored in order to evaluate digester performance.
5. List various clues and factors for determining digester problems.
6. Describe routine operations for a digester.
7. Describe the start-up procedure for a digester.
8. List principal operating problems in anaerobic digesters.
9. Identify monitoring and inspection procedures for investigating operational problems in anaerobic digesters.
10. Determine the correct actions to take to correct operational problems in anaerobic digesters.

Training Materials:

Student Notebook, pages SH-1 thru SH-3, process diagrams reproduced from EPA Process Design Manual, "Sludge Treatment and Disposal"

Slide series of 15 picture slides on anaerobic digesters, with slide key

Slide series of 7 word slides, and key

Process of Troubleshooting Chart

Student Notebook page SH-4, Start Up Procedure for Digesters

EPA Manual "Evaluating the Performance of Wastewater Treatment Plants," pages 114-199

Classroom Set-up:

A normal classroom set-up will be required. Students should be seated with their student groups.

35 mm carousel slide projector with remote controls

Large screen (8 ft x 10 ft)

Chalkboard or easel

Pointer

Subdivision Schedule:

Within the 1 hour time period, the following schedule should be observed in presenting the lesson plan outline.

Time	Subject
0-10 Minutes	Introduction to Solids Handling
10-20 Minutes	Fundamentals of Anaerobic Digestion (lesson outline)
20-35 Minutes	Fundamentals of Anaerobic Digestion (slides)
35-60 Minutes	Troubleshooting Anaerobic Digesters

Subdivision Approach:

The instructor is to rely upon the lesson outline, and particularly upon the slide series and slide key. Student input and discussion is to be encouraged and stimulated by the instructor.

LESSON OUTLINE

I. Introduction to Solids Handling (10 Minutes)

A. Proper disposal of solids – is one half the challenge of designing and operating a wastewater treatment plant.

1. Concern for a good effluent often puts the question of solids in the background.
2. Solids volume is very large – presents handling and processing problems.

B. Reuse of solids – In certain situations the reuse of solids may be economical and productive – at least more economical than other forms of disposal.

1. Land spreading of sludge is most common form of reuse.
2. Processing into dry fertilizer is practiced in some places with varying degrees of success.
3. There are now processes that can stabilize sludges into construction type materials.

C. Troubleshooting of Solids Handling Problems

1. Problems with solids in treatment plants are numerous and frequent.
2. Solids problems can easily lead to many other operational problems among the treatment processes.

D. There are many processes for treating and handling solids, some of which are covered in this course. These include:

anaerobic digestion
drying beds
dissolved air flotation
  thickening
vacuum filtration
gravity thickening
centrifugation
aerobic digestion
chemical conditioning
Imhoff tanks
spiragestors and
  claragestors
zimpro
sludge lagoons
belt and coil filters
sludge presses
handling of grit,
  screening and scum
single stage and open
  digestors
land application

KEY POINTS & INSTRUCTOR GUIDE

Key Point: Stress the importance of solids handling in treatment plant operations.

Key Point: Troubleshooters should keep an eye out for solids handling problems.

LESSON OUTLINE

E. Purpose of this lesson
   1. To identify and investigate problems that occur in various solids handling processes.
   2. To review the causes of such problems, how they are identified, and how they are solved.
   3. To stress the use of the Process of Troubleshooting in solving solids handling problems.
   4. To focus on troubleshooter behavior and the means for troubleshooters to provide technical assistance.

II. Fundamentals of Anaerobic Digestion (25 Minutes)

A. Description of anaerobic digestion (in terms that the operators of small plants might use)
   1. Bacteria in the sludge help to gasify the organics in the sludge.
   2. The bacteria produce carbon, and energy.
   3. Digestion does not completely stabilize the sludge.
   4. The digester can be described as being a big "stomach," doing the same things that a person's stomach does.

B. Contrast this description with the textbook description, which if used by the troubleshooter, would probably "turn-off" the operator forever, and make technical assistance impossible.
   1. Textbook description

      Anaerobic digestion of domestic sewage sludge is the process whereby anaerobic and facultative bacteria liquefy and gasify the organic portion of the sludge in order to obtain energy and certain elements, such as carbon, for the synthesis of their protoplasmic production. Anaerobic digestion is not a complete stabilization process since many of the organic constituents resist biological decomposition; for example, carbohydrates and short-chained fatty acids are catobolized more rapidly in the process than fats and oils.

KEY POINTS & INSTRUCTOR GUIDE

Guide: List purposes on chalkboard or easel so that class may readily identify.

Guide: Instructor should refer students to the Process of Troubleshooting Chart.

Guide: In addition to its content, this section emphasizes the importance of communication in troubleshooting and in dealing with operators.

Key Point: The basic problem in engineer communication with operators is too much theory.

LESSON OUTLINE

C. Emphasize the importance of gas production as a part of the process of anaerobic digestion – it is an indicator of the health of the process.

D. Process Diagrams

1. These diagrams are reproduced for the students from EPA Process Design Manual "Sludge Treatment and Disposal," Chapter 5. For detailed information the students should obtain the manual.
   - a. Standard digestion page SH-1
     1. unheated
     2. unmixed
   - b. High rate digestion, page SH-1
     1. most digesters are now high rate digesters
     2. heated
   - c. Two stage anaerobic digestion, page SH-2
     1. Primary digester
        - a. usually fixed cover
        - b. some are converted from secondary digesters with floating cover
        - c. heated
        - d. completely mixed – mechanical or gas mixing
        - e. piping layout may cause operational difficulties in converted digesters
     2. Secondary digester
        - a. may have floating or gas holder cover
        - b. unmixed and unheated
        - c. principal function is to separate solids
   - d. Anaerobic contact digestion, page SH-3
     1. this variation is usually achieved in piping arrangements

E. Additional equipment needed for anaerobic digestion

1. Mechanical or gas mixing equipment
2. Heating equipment – to maintain the system at a constant 95°F temperature

KEY POINTS & INSTRUCTOR GUIDE

Guide: Refer students to process diagrams reproduced in Student Notebook pp. SH-1 thru SH-3.

Review each diagram very briefly with the class.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
F. Slide Series on Anaerobic Digestion (15 Minutes) Instructor should follow slide key. Emphasize operational aspects of digesters, and evidence of poor operation in the pictures. There are 15 slides for this 15 minute segment. Note to class that it is difficult to show some operational problems on picture slides, but that the slides give a good overview of anaerobic digesters.	Guide: Try to have *students* identify problems depicted by the slides. Instructor should ask "can you see anything here that would cause the operator problems?" or "What problems do you see here?" etc. Use the slides to obtain class input.
1. Anaerobic digestion tankage under construction	SLIDE SH-1
2. Another *anaerobic digester* of which only the fixed cover, pressure and vacuum breakers, flame arrestor, and gas exit line are visible above ground. This one extended 32 feet below ground level.	SLIDE SH-2
3. In warm climates above ground *digesters* are used. The primary digestion unit in the background is piped for connection to the secondary digester partially shown in the right lower corner. Grivity flow seldom works for conducting digested sludge from the bottom of the secondary digester to ground level sludge drying beds. Getting sludge out of these units without pumps became a real problem. There wasn't enough gas so they used air pressure. (This took care of anaerobic digestion and created a potential bomb.)	SLIDE SH-3 Ask class to comment on using air pressure.
4. This top of a fixed cover *anaerobic digester* includes complex arrangements for power to internal mechanical mixers below the enclosed box on the left, vacuum relief and flame arrestor in front of the box, gas outlet piping, access manholes, supernating box in the right background. A few other items are not visible such as sample holes, level indicators, etc.	SLIDE SH-4
5. Floating cover *digester*. This skewed piping high and to the left was installed for gas recirculation that didn't work. The "His" label on the top box went with a "Hers" on	SLIDE SH-5

LESSON OVERVIEW	KEY POINTS & INSTRUCTOR GUIDE
an adjacent digester not shown. This was public relations working on a suggestion from a yacht basin enthusiast just outside the plant grounds. A large condominium was located within 300 feet. This operation has to be good and was.	
6. Since the gas mixing wasn't satisfactory a four-inch centrifugal pump was used for continuous mixing bottom to top.	SLIDE SH-6
7. This *heat exchanger* is on the circulating sludge line to keep the temperature uniform and within favorable operating levels. Heat exchangers require a good deal of maintenance and concern in order to function reliably.	SLIDE SH-7
8. The digester is widely advertised for energy recovery purposes. In this case gas fueled power is being used to drive an air compressor.	SLIDE SH-8
9. Anaerobic digestion is an expensive capital, operation and maintenance unit. The waste gas burner frequently appears to be the hardest working part of it. During cold weather most of gas is used for heating the digester; switchover from one fuel to an alternate frequently isn't practiced, a good indication of poor operation.	SLIDE SH-9
10. The viewer is correct, this floating cover isn't level.	SLIDE SH-10
11. A common occurrence when the cover isn't level is represented here on another digester. The gas is bubbling through the water seal on the tilted cover and spattering solids over the top. This one was a deliberate tilt because	SLIDE SH-11
12. The gas line from the *digesters* to the gas holder about 1,000 feet away had corroded and wasn't repaired. The gas went into the air because of the lack of usable pipe line. It is not understood why the designer positioned the producer and storage units quite so far apart, but unfortunately, it isn't that unusual.	SLIDE SH-12

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
13. Supernatant returns do not have to be a troublesome return flow problem. This series of 3-500 gallon tanks took care of side-loop supernatant treatment for a 1.6 MGD plant. At first, one tank was being filled, one tank for dosing with about 250 mg Alum – Al/liter and mixed while the third was settled. The clarified liquid returned to process and the solids concentrate pumped to disposal. These tanks were later converted to a flow through operation.	SLIDE SH-13
14. You won't often see 2 x 2 x 3 foot concrete blocks at about 15 feet center to center spacing to hold a digester floating cover down. It did, as you see from the sludge residues on the blocks.	SLIDE SH-14
15. This is the same cover showing sludge drying bed area almost completely covering the "floating" cover. This plant had been in operation slightly over two years. It was a complete secondary plant including vacuum filtration and incineration. One maintenance man and two operators were on board where 17 had been recommended. The operating requirements called for a discharge limit of about 111 BOD$_5$ and 140 mg SS/liter. It didn't take much operation to meet the limit. There had been no sludge disposal. Everything was full, which again is not uncommon, but certainly not desirable.	SLIDE SH-15
	Guide: Following the slides, the instructor should call for comments and questions before going on to the next section.
III. Troubleshooting Anaerobic Digesters (25 Minutes) For a good overall presentation of the operations of anaerobic digesters, including troubleshooting, the instructor should refer the class to "Operations Manual – Anaerobic Sludge Digestion" by Zickefoose & Hayes. Stevens Thompson & Runyan Inc., for EPA, Feb. 1976.	

LESSON OUTLINE

A. Using the Process of Troubleshooting for problems with anaerobic digestion.

1. "TROUBLESHOOTING ANAEROBIC DIGESTION INITIAL PLANT VISIT ACTIVITIES"
   - Talk to operator, get background on plans
   - Study piping, pumping, heating
   - Analyze process controls
   - Find out what operator has been doing
2. "NORMAL PROCESS MONITORING – ANAEROBIC DIGESTION"

Daily	Weekly
pH	Alkalinity
Temperature	Volatile Solids
Gas Production	Fixed Solids
	Volatile Acids

3. Troubleshooters, like detectives, must look for clues in order to solve the mysteries of plant breakdown.
   a. "TROUBLESHOOTING CLUES"
      - Unusual operating procedures
      - Monitoring parameters – unusual results
      - Unusual staff behavior
      - Suspicious records
      - Other????

   b. Relate the following story as an example of troubleshooter "detective work."

      A few years ago, a new gas holder secondary digester was built at an existing plant, and the existing secondary digester with a floating cover was changed into a primary digester.

      The digesters were placed back on line and seemed to be doing well. Then it was noted that the fixed cover primary digester was not supernating when sludge was being pumped in, and the gas holder cover rose rapidly when pumping to the old primary digester.

KEY POINTS & INSTRUCTOR GUIDE

Refer students to Troubleshooting Chart.

SLIDE SH-16 (word)
Use this slide to introduce the use of the Process of Troubleshooting. Stress the troubleshooter's attitude and behavior.

SLIDE SH-17 (word)

SLIDE SH-18 (word)
Use this slide to discuss the analytical approach to troubleshooting. Seek class input into other possible clues.

LESSON OUTLINE

It was very puzzling and the problem wasn't solved until the troubleshooter stayed late one day and started to discuss the situation with the evening shift operator. He found that the operator continued to operate the new digester as he had the old system, which was to transfer the bottom of the fixed cover digester to the old secondary digester every night. There was no harm done because the gas piping was interconnected between all the digesters and the gas from the gas holder filled the top of the digester he pumped down.

He also did not transfer enough to allow the gas to escape out the overflow piping.

c. What were the "clues" or indicators of plant problems?
   1. Primary digester – not supernating
   2. Rising of gas holder cover

d. How was the cause of the problem found?
   1. By persistence – remaining late at the plant
   2. By talking to, and listening to the evening shift operator

e. What does this story signify in terms of troubleshooting efforts?

4. "FACTORS FOR PROCESS EVALUATION"
   Anaerobic Digester
   - Gas production – actual vs. computed
   - Solids loading (volatile matter) 0.05 to 0.2 lb/ft^3/day
   - Hydraulic detention time 15 to 30 days
   - Rate of feed and withdrawal

5. "EXPECTED ANALYTICAL RESULTS"
   - Alkalinity – 2,500 mg/l
   - Volatile acids – less than 800 mg/l
   - Gas – 30 % – 40% CO_2

KEY POINTS & INSTRUCTOR GUIDE

Guide: Following the story, the instructor should ask the class to discuss the story from a troubleshooting perspective.

Instructor should seek student input.

SLIDE SH-19 (word)

Instructor should note that these are things to look for while troubleshooting digesters.

SLIDE SH-20 (word)

Troubleshooters should compare what they observe to expected analytical results.

LESSON OUTLINE

- Raw sludge – 3- 8% solids
  70-80% volatile
- pH – 6.8 to 7.2
- Volatile matter reduction – 50% to 80%

B. The troubleshooter should have a good sense of the routine operations of a digester.

In visiting a plant, observations that show deviations from standard operating procedures may give clues to problems.

1. "ROUTINE DIGESTER OPERATIONS"
   - Continuous feeding of sludge
   - Monitor key parameters
   - Record sludge input, withdrawal
   - Monitor gas production
   - Compute solids input and output
   - Check temperature profile periodically
   - Measure sludge level, temperature, digester pressure, cover height
2. Troubleshooters should be aware of how to start up a digester
   a. Fill with raw sewage
   b. Heat to desired temperature (approximately 95°F)
   c. Feed digester at 0.01 lb of VM/ft^3/day
   d. Compute volatile acids, alkalinity, plus pH daily
   e. Buffer the system with lime or sodium carbonate
   f. Plot volatile acid concentration as a function of time
   g. Mix digester continuously if possible and maintain constant temperature
   h. As soon as volatile acid concentration starts to drop rapidly increase loading by 0.01 lbs of VM/ft^3/day
   i. Continue until full load is on system
   j. Seed sludge can be added to accelerate the start up process provided it can be added in sufficient quantity (10% of tank volume) and not be cooled or aerated in the transfer process

KEY POINTS & INSTRUCTOR GUIDE

SLIDE SH-21 (word)

Key Points: These are the principal activities of routine digester operation.

Refer students to Student Notebook, page SH-4, for information on digester start up.

LESSON OUTLINE

C. Operational Problems in Digesters

1. "PRINCIPLE OPERATING PROBLEMS IN ANAEROBIC DIGESTERS"
    - No gas production
    - Scum blanket in tank
    - Increase in ratio acid/alkalinity
    - Foam in digester
    - Low reduction of volatile solids
    - High supernatant solids concentration
2. Have students refer to pp 114-119 of EPA Manual, "Evaluating the Performance of Wastewater Treatment Plants."
    a. identifying problems
    b. monitoring and inspecting
    c. correcting operational problems
3. Advise students to look over this material in detail — there will be opportunity later in the lesson for questions and detailed discussion.
4. Note also that there is a detailed trouble-shooting guide, Section 1, in the "Operations Manual — Anaerobic Sludge Digestion" by Zickefoose and Hayes.

D. Instructor should complete this subdivision with questions and discussion from students on anaerobic digesters.

KEY POINTS & INSTRUCTOR GUIDE

SLIDE SH-22 (word)

Stress problem solving information on these problems in EPA Manual, briefly review with students.

SOLIDS HANDLING

Lesson Plan – Subdivision 2 **Time: 110 Minutes**

Title: Problem Solving in Anaerobic Digestion – "Fishbowl" Technique

Instructor Objectives: To have students confront realistic operating problems in anaerobic digestion, and realistic situations regarding operator competence and attitude. To have students apply the Process of Troubleshooting within their student groups. To utilize "role playing" techniques so that realistic operator-troubleshooter relationships can be developed. To utilize the "fishbowl" technique so that students may observe others carrying out the process of troubleshooting and thus provide feedback as well as learn from others.

Student Objectives: As a result of this lesson subdivision, students will be able to do the following:

1. Employ the elements of the "Process of Troubleshooting" in analyzing operational problems in anaerobic digestion.
2. Experience and observe some of the problems confronted by wastewater treatment plant operators.
3. Critique the troubleshooting technique of others, and thus observe their positive and negative attributes in applying the process of troubleshooting.
4. Have their troubleshooting techniques critiqued by others.

Training Materials:

The training materials for this lesson subdivision are instructions that are provided to the participants in the problem solving-role playing exercises to be carried out by the students. Two problems will be analyzed by student troubleshooting groups. The training materials provided are:

1. Problem 1 – Instructions to troubleshooters
2. Problem 1 – Instructions to operating personnel
3. Problem 2 – Instructions to troubleshooters.
4. Problem 2 – Instructions to operating personnel
5. EPA Manual "Evaluating the Performance of Wastewater Treatment Plants" may be used by student troubleshooter groups as a reference.

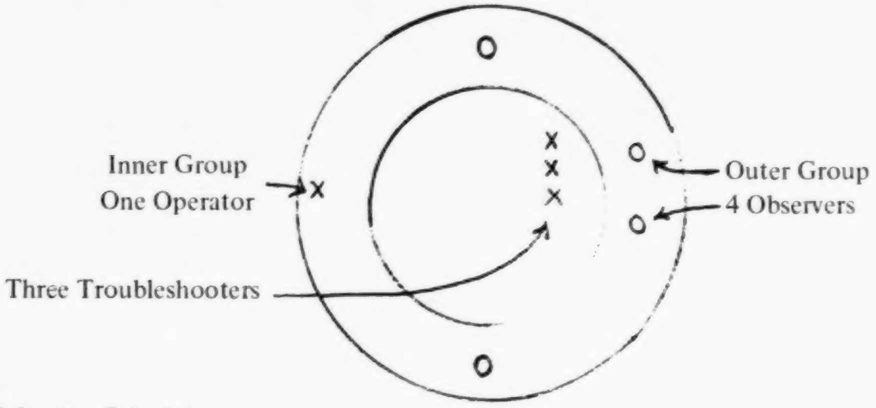
Classroom Set-up:

The classroom should be set up to accommodate groups of eight (8) students. If possible, to avoid distraction from one group to another, separate rooms should be used for each group of 8.

Each group of 8 consists of two (2) four-man groups, an "inner" group who are actually participating in the role playing-problem solving, and an "outer" group who are observing.

Each "inner" group consists of three (3) troubleshooters, and one student who is playing the operator's role.

Each group of 8 should be arranged as in this diagram.



Subdivision Schedule:

Within the 110 minute time period, the following schedule should be observed in carrying out this lesson subdivision.

TIME	ACTIVITY
0 – 10 Minutes	Instructor introduces lesson, sets up groups, provides instructions. Groups occupy location designated for them.
10 – 20 Minutes	Troubleshooting groups, and operators, prepare their approaches to Problem 1.
20 – 40 Minutes	Designated groups analyze and troubleshoot Problem 1.
40 – 50 Minutes	Observers for Problem 1 report their findings.
50 – 60 Minutes	Troubleshooting groups, and operators, prepare their approaches to Problem 2.
60 – 80 Minutes	Designated groups analyze and troubleshoot Problem 2.
80 – 90 Minutes	Observers for Problem 2 report their findings.
90 – 100 Minutes	Entire class convenes, discusses its findings and experience with the "instructor."

Subdivision Approach:

The approach to this lesson subdivision employs two educational techniques that allow the students to participate in and experience the Process of Troubleshooting.

1. One technique is "role playing." For each problem, a four-person group is assigned, with one person playing the role of the operator – with specific instructions, and the other three persons playing the role of troubleshooters.

The second technique is the "fishbowl" technique, where one group observes the other group carrying out the role playing exercise in attempting to solve the assigned problem. The observing group should take notes on what they see, and report back at the appropriate time.

The group involved in "role playing" to solve the assigned problem is known as the "inner group" (inside the fishbowl) and is seated accordingly. The group of observers is known as the "outer group."

Groups for this lesson subdivision must be pre-designated by the instructor, and should be as balanced as possible in composition so that all groups are roughly comparable.

2. The individual selected to play the role of "plant operator" from each group should be a person who is relatively experienced in the inspection of treatment plants, compared to his fellow students. The selected individuals should also be chosen from among those who have personalities which would make them not reticent to participate. The individuals who are to be "plant operators" should be pre-selected, and given their instructions in advance of this lesson subdivision.

3. It is very important that the observers be encouraged to give honest feedback to the troubleshooters – after the 20 minute troubleshooting exercise is completed. It is this feedback that provides much of the learning experience for this lesson.

4. After one problem has been analyzed, and feedback provided, the groups must switch, so that the "inner" and "outer" groups change places. A new "operator" and new troubleshooters then address the second problem, with the new observers taking notes.

5. After both problems have been analyzed and feedback is reported by the observers, it is important for the instructor to bring the entire class together to discuss the results, and for the students to discuss their role playing experiences. This overall comparison of what occurred in each group is an essential conclusion to this exercise that allows the students to compare notes and obtain an overall impression of the troubleshooter-operator relationship.

6. Some students may be very timid in their role playing involvement. In trial presentations, a very small percentage (1%) were very negative and even belligerent. The instructor must "cruise" from group to group to see that people participate and to encourage them to do so. However, if a student's attitude is so negative as to disrupt the others, he should be excused from this portion of the lesson.

Details on administering the lesson are provided in the lesson plan outline.

LESSON OUTLINE

I. Prior to start of lesson

- A. Student groups should be designated by Course Director or instructor
- B. Instructor should choose one member of each group to play the role of "operator."
  - 1. Distribute "Instructions to Operating Personnel" to persons selected as operators.

II. Introduction (10 Minutes)

- A. Introduce lesson
- B. Announce group composition
- C. Select groups to be "inner" or "outer" groups
- D. Emphasize to students playing the role of troubleshooters that they should –
  - 1. Work as a team in questioning the "operator"
  - 2. Use the "Process of Troubleshooting," i.e. – be analytical
  - 3. Find the answer and solve the operator's problem in 20 minutes
- E. Emphasize to the "outer" group of observers to take notes and be prepared to comment on how well the troubleshooters perform.
- F. Privately emphasize to the students acting as operators for Problem 1 that they are to be *cooperative but inexperienced.* In response to any question that is not covered in the operator's instruction sheet they are to indicate that they don't know the answer. If the inspectors give detailed instructions on how to obtain the answer, the operator will agree to get the answer and call the inspector back tomorrow.
- G. Have student groups go to their assigned places for Problem 1.

III. Preparation (10 Minutes)

- A. Allow troubleshooting groups and operators 10 minutes to prepare their approaches to Problem 1.

KEY POINTS & INSTRUCTOR GUIDE

Guide: Instructions are available as part of course materials. They must be reproduced prior to the lesson (See p. SH2-8 for instructions).

Time 10-20 Minutes.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
IV. Problem 1 (20 Minutes)	Time 20-40 Minutes.
A. Instructor should make sure "inner" and "outer" groups go to their respective seats	
B. Instructor should "cruise" from group to group to oversee the exercise	
C. Call time after 20 minutes	
V. Feedback for Problem 1 (10 Minutes)	Time 40-50 Minutes
A. Observers should report their findings on how the troubleshooters performed	
B. After 10 minutes, have groups switch places for Problem 2	
C. Privately emphasize to the students acting as operators for Problem 2 that they are to be reluctant and defensive to the point of thinly veiled hostility. In response to any question that is not covered in the operator's instruction sheet, they are to indicate that they don't know the answer. If the instructors ask for additional information or data, the operator cannot, will not, or does not have time to furnish it.	
VI. Preparation (10 Minutes)	Time 50-60 Minutes
A. Allow troubleshooting groups and operators 10 minutes to prepare their approaches to Problem 2	
VII. Problem 2 (20 Minutes)	Time 60-80 Minutes
A. Instructor should make sure "inner" and "outer" groups go to their respective seats	
B. Instructor should "cruise" from group to group to oversee the exercise	
C. Call time after 20 minutes	
VIII. Feedback for Problem 2 (10 Minutes)	Time 80-90 Minutes
A. Observers should report their findings on how the troubleshooters performed.	
B. After 10 minutes, bring the entire class back together to review the problems, the observations, and the results of the exercise	

LESSON OUTLINE

IX. Discussion of findings and Results

A. Brief review of results of the troubleshooting problems

1. Problem 1

   If the inspectors follow the previously emphasized troubleshooting techniques, the most obvious cause should become apparent.

   The digester is organically overloaded and the operator should reduce or cease pumping raw sludge to the digester.

   He should add lime to raise the pH and continuously recirculate the digester contents through the heat exchanger to gradually raise the temperature to 95°F.

   The inspector should have the operator start this corrective program immediately and then assure the operator that he will be at the plant as soon as possible to confirm and assist.

2. Problem 2

   If the inspectors follow the troubleshooting techniques and ask the right questions, the most obvious or most probable cause should become apparent.

   The digesters have probably received a slug of toxic material, possibly heavy metals, and the operator should continue his present procedure.

   The inspector should visit the site and collect samples of digester sludge, sludge from drying beds, raw sludge, and raw sewage to determine the presence of toxic material. If toxic materials are present, they should be identified and their concentrations determined.

KEY POINTS & INSTRUCTOR GUIDE

Time 90-110 Minutes

Key Points: The instructor should cover the technical solutions as quickly as possible. Focus discussion on the observed behavior of troubleshooters and operators.

LESSON OUTLINE

The final solution will depend upon the type of toxic material present. Overall heavy metals concentrations may be reduced by the addition of sodium sulfide. Cyanide and chromium may require that the digesters be emptied and cleaned.

B. Discuss with class whether or not the troubleshooters approached the problems by using the Process of Troubleshooting.

C. Was the "operator" behavior realistic. Ask class whether or not they have met operators as portrayed.

D. What aspects of troubleshooter-operator behavior were observed in the exercise?

KEY POINTS & INSTRUCTOR GUIDE

Key Points: Discuss these key points of this lesson with the class, by maximizing class input.

NOTE ON DISTRIBUTION OF INSTRUCTIONS

The following sets of instructions must be reproduced prior to this lesson, and distributed to students for the lesson.

Distribution:

"Instructions to Troubleshooters" go to each troubleshooter and each observer.

"Instructions to Operators" go only to students playing the role of "Operator," and to each observer.

For example, if there are 32 students in the class, there would be eight (8) groups of four (4) students each. Four groups would work on Problem 1 and observe Problem 2. The other four groups would observe Problem 1 and work on Problem 2. For a class with 32 students, the number of copies of instructions needed are:

Instructions to Troubleshooters – 28 copies of each
Instructions to Operators – 20 copies of each

Plus extra copies for instructor and other interested persons.

SOLIDS HANDLING – SUBDIVISION NUMBER 2

PROBLEM SOLVING IN ANAEROBIC DIGESTION

Problem Number 1 – Instructions to Inspection Personnel

You are a district engineer for the State Environmental Protection Agency. It is early Monday morning and you receive a telephone call from an operator in your district.

He reports that foam is being discharged from the upper level supernatant line and foam is visible through the sight glasses in the digester roof

The plant is a 1 MGD trickling filter unit with a fixed cover anaerobic digester and the last time you visited the plant was 6 months ago.

The operator is uncertified and has been on the job for about a year. He is cooperative but relatively inexperienced. He is concerned and asking for help.

You inform the operator that you expect to be in his vicinity later in the morning, and will be traveling with some of the other field staff persons from your office, so you'll bring them along.

When you arrive at the plant, you begin your troubleshooting procedures.

SOLIDS HANDLING – SUBDIVISION NUMBER 2

PROBLEM SOLVING IN ANAEROBIC DIGESTION

Problem Number 1 – Instructions to Operating Personnel

1. You are the operator of a 1 MGD trickling filter plant with a single anaerobic digester.
2. You are an uncertified operator and, in addition to the wastewater treatment plant, you also operate the water plant, collection system, and water distribution system.
3. On Monday morning when you arrive at the plant, you discover foam being discharged from the upper level supernatant line and, when you investigate the cover, you see foam through the sight glasses.
4. Your anaerobic digester is a fixed cover unit with no mechanical or gas mixing equipment. Total recirculation is possible and the unit is heated by an external heat exchanger.
5. You immediately call the State agency engineer assigned to your district and ask for assistance. He has not seen your plant for 6 months.
6. In response to specific questions, you supply the following data. (If you knew what data was important and how to properly interpret the data, you would not have called for assistance):
   a. pH – today 6.6, Friday 7.0, Thursday 7.0, Wednesday 7.0, Tuesday 7.0
   b. Temperature – today 92°F, Friday 95°F, Thursday 95°F, Wednesday 95°F, Tuesday 95°F
   c. Volatile Acids – 800 mg/l last Monday, have not run today
   d. Alkalinity – 2,700 mg/l last Monday, have not run today
   e. Laboratory not equipped to perform solids analyses
   f. Laboratory not equipped to perform gas analysis
   g. Gas has "sour" odor, but is still burnable with orange colored flame

h. No records are kept on amount of raw sludge pumped to digester.

i. No sludge has been withdrawn from digester for over a month.

j. Nothing unusual occurred last week when you were on duty. The only thing that you can remember is that a flight chain broke on number one primary settling tank Friday.

k. You instructed the weekend operator to dewater number one primary settling tank on Saturday and Sunday so you could repair the chain Monday.

l. There are no significant industries connected to the system.

m. Lime is available at the water plant.

Instructions on Operator Behavior

You are a cooperative but inexperienced operator. If you receive any questions for which the answers are not provided in these instructions, indicate that you do not know the answer. If the inspector gives you detailed instructions on how to obtain the answer, agree to try to get it and indicate that you will call him back tomorrow with the answer.

SOLIDS HANDLING – SUBDIVISION NUMBER 2

PROBLEM SOLVING IN ANAEROBIC DIGESTION

Problem Number 2 – Instructions to Troubleshooters

You are a district engineer for the State Environmental Protection Agency. You have just received a call from an irate, hostile, and concerned citizen. She lives 600 yards down-wind from a municipal wastewater treatment plant. She states that the plant smells terrible and that the odor is making her ill and the condition has existed for three days. She demands that you take action, since she has called the treatment plant and the plant operator hung up while she was speaking.

Before calling the plant, you pull the file and study the problem. The plant is a 2 MGD activated sludge plant with two anaerobic digesters. The plant serves a community of some 12,000 people and several small industries. The industries are typical for a small community in your state, a poultry processing plant, a cheese and dairy products plant, a clothing manufacturing plant, an electrical equipment manufacturing plant, and an automobile specialty products plant.

The monthly operating reports indicate consistently good results for the past year. The operator is certified under the grandfather clause and has over twenty-five years experience. The last state inspection of the facility was eighteen months ago. Youccall the plant, and above the protests of the operator, tell him you'll be there in an hour with a couple of "boys" from your office to see what's going on. You take along your notes on the "Process of Troubleshooting," because you figure if ever you needed some help, this was going to be the time!

SOLIDS HANDLING – SUBDIVISION NUMBER 2

PROBLEM SOLVING IN ANAEROBIC DIGESTION

Problem Number 2 – Instructions to Operating Personnel

1. You are the operator of a 2 MGD activated sludge plant with two anaerobic digesters.

2. You are certified under the grandfather's clause, because you have twenty-five years experience and did not have to take a test designed by some young engineer.

3. The anaerobic digesters are floating cover units of equal size with gas mixing equipment and external heat exchangers. Digested sludge is dewatered on sludge drying beds.

4. For the past week you have been working twelve hours a day with two sick digesters and for the past three days people have been complaining and demanding that you do something. To top off your day, that young engineer from the district office has just called to offer his help.

5. The digesters were both full when you noticed the gas production and pH drop. The last time that happened the cheese plant had slugged the treatment plant. To cure the problem, you raised the pH with lime and rested the digesters. This is what you are doing now, except you had to fill two drying beds with sludge in order to have room to mix the lime. The beds and what little gas is being produced have a septic smell.

6. You will answer specific questions from the state engineer but you will not offer him any extra information.
   a. pH – 6.1 on both digesters – prior to the failure, pH varied between 7.1 and 7.2 on both digesters.
   b. Volatile Acids – 4,000 mg/l – prior to the failure, 400 mg/l on both digesters.
   c. Both digesters are operated as single-stage complete mixing digesters, as described in hand-out as "High Rate Digestion" and are fed on an alternating basis.
   d. Alkalinity – 1,200 mg/l – prior to the failure, 2,400 mg/l on both digesters.
   e. To date you have added 1,500 lbs of lime to each of the digesters and have succeeded in stopping the pH drop. The pH has not yet raised.

f. The temperature in each unit is 95°F, and it has remained constant.

g. Prior to the failure the gas mixing system was operated on a daily basis and scum is not a problem.

h. Total solids content is between 6 and 8 percent.

i. Volatile solids content of sludge is approximately 60 percent.

j. The rate of feed to the digester has remained constant.

k. The sludge and what little gas is being produced does not have a "rotten egg" odor. The odor is similar to the smell of rancid butter.

l. Since you have not been pumping raw sludge to the digesters at a normal rate, there is a sludge build-up in the primary settling tank. This sludge is becoming septic and floating to the top.

m. The pH drop occurred overnight and the usable gas production ceased overnight.

n. Your grit collector works well and there is no large accumulation of grit in the digesters.

o. You have no laboratory capability for heavy metals determination.

Instructions on Operator Behavior

You're getting near retirement, and you don't really like other people meddling around your plant. You are reluctant to provide information and are defensive, particularly because that "old lady" living down the road has been calling day and night to complain, and you know she's right. The city manager has also been getting calls, and that really makes you mad.

You decide you'll be on "good behavior" when the state inspector arrives. You're upset because you're about to receive a 25 year award from the State Water Pollution Control Federation Chapter, and you don't want this incident to spoil it.

SOLIDS HANDLING

Lesson Plan – Subdivision 3 **Time: 90 Minutes**

Title: Other Methods of Solids Handling

Instructor Objectives: To present the basic elements of six solids handling processes, and the equipment used for those processes. To discuss normal operations of the processes, process evaluation techniques, and approaches to troubleshooting the principal operating problems in each process discussed. The processes of solids handling presented are: gravity thickening, dissolved air flotation thickening, centrifugation, aerobic digestion, sludge drying beds, and vacuum filtration.

Student Objectives: As a result of this lesson subdivision, students will be able to do the following:

1. List and identify unit processes of solids handling
2. Identify the basic elements of six unit processes of solids handling: gravity thickening, dissolved air flotation thickening, centrifugation, aerobic digestion, sludge drying beds, and vacuum filtration
3. Describe the normal operations of each of these processes
4. Identify and carry out process evaluation tests and observations to control each of the processes named above
5. Identify significant operating problems in each of the solids handling processes discussed, and their causes
6. Apply corrective actions to each of the problems identified

Training Materials

Slide series, 24 word slides and key

Slide series, 8 picture slides on aerobic digestion, and key

Nine Student Notebook pages, process diagrams on methods of solids handling

Six Student Notebook pages, Troubleshooting Guide, Solids Handling

Supplemental Information on Solids Handling Processes (provided for instructor's use and background at the end of the lesson plan outline)

EPA Process Design Manual "Sludge Treatment and Disposal"

Classroom Set-up:

A normal classroom set-up will be required

Students should be seated with their student groups

35 mm carousel slide projector with remote controls

Large screen (8 ft x 10 ft)

Chalkboard or easel

Pointer

Subdivision Schedule:

- Within the 90 minute time period, the following schedule should be observed in presenting the lesson plan outline

TIME	SUBJECT
0 – 10 Minutes	Introduction to Solids Handling Processes
10 – 20 Minutes	Gravity thickening
20 – 30 Minutes	Dissolved air flotation thickening
30 – 40 Minutes	Centrifugation
40 – 60 Minutes	Aerobic digestion
60 – 70 Minutes	Sludge drying beds
70 – 80 Minutes	Vacuum filtration
80 – 90 Minutes	Summary and questions

Subdivision Approach:

1. The instructor is to follow the lesson outline. word slides are used throughout the lesson subdivision, to introduce topics and should be used by the instructor as a focal point for discussion on the topic presented. Student discussion should be encouraged.
2. Section V, Aerobic Discussion, contains a series of 8 picture slides, and slide key
3. The instructor is asked to make frequent reference to the Student Notebook materials, which contain process diagrams and a troubleshooting guide for each process discussed.
4. Because this is a long subdivision with little variation in approach, it may be presented in two separate segments with a break in between.
5. Note on topics presented: The six processes of solids handling presented in this subdivision are six of the most common solids handling processes found around the nation. If the course is presented in a region or a state where one or more of these processes are not common, that portion of the lesson should be deleted. Other processes may be substituted by the instructor if they are of particular interest in the location of the course.

LESSON OUTLINE

I. Introduction to Solids Handling Processes (10 Minutes)

A. Different sludge handling processes have different functions – each has its own factors to consider in

1. Whether or not to include in a plant
2. Actual design
3. Operation
4. Maintenance

"SOLIDS HANDLING UNIT PROCESSES"

- Thickening (Blending)
- Stabilization (Reduction)
- Conditioning (Stabilization)
- Dewatering
- Heat drying
- Reduction (Stabilization)
- Final Disposal

B. Functions of various unit processes of solids handling

1. Each of the unit processes provides several functions in the handling of treatment plant sludge
2. Briefly review Notebook page SH-5 with class, and review the function of each unit process.

C. Types of solids handling processes

1. Each unit process is typified by several specific processes
2. In most regions, many of these different processes may be found
3. Briefly review Notebook page SH-6 with class, noting the types of processes which will be covered in the remainder of this lesson
   a. Gravity thickening
   b. Dissolved air flotation
   c. Centrifugation
   d. Aerobic digestion
   e. Sludge drying beds
   f. Vacuum filtration and land disposal will be covered in the following lesson on land treatment

KEY POINTS & INSTRUCTOR GUIDE

Guide: Illustrate processes by Slide SH-23.

SLIDE SH-23 (word)

Refer to Notebook page SH-5 Sludge Treatment Processes.

Refer to Notebook page SH-6 Unit Processes – Sludge Processing and Disposal.

Note: In some areas, some of these processes may not be used, and should be excluded from the lesson.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
4. Instructor should point out which processes are most widely used in the area where the course is being presented.	
II. Gravity Thickening (10 Minutes)	
A. A gravity thickener resembles a clarifier – where sludge settles and thickens. Briefly discuss diagram with students	Guide: Refer to Notebook page SH-7 Gravity Thickener.
B. Troubleshooting Gravity Thickeners 1. Troubleshooters should be familiar with normal operating procedures and conditions	
"GRAVITY THICKENERS – NORMAL OPERATIONS" • Sludge pumped continuously into thickener • Concentrated sludge should be removed continuously • Small plants – remove hourly • Check concentrations daily • Check supernatant solids weekly	SLIDE SH-24 (word)
2. To evaluate a gravity thickening process, troubleshooters should test and determine the following parameters	Guide: To discuss process evaluation, use Slide SH-25.
"TROUBLESHOOTING GRAVITY THICKENERS PROCESS TESTS" • Hydraulic loading • Solids loading • Compute mass balance in system • Immediate oxygen demand (IOD) • Average underflow and overflow solids concentrations	SLIDE SH-25 (word)
3. Important troubleshooting observations a. Observe surface for gas bubbles b. Odors	Guide: Once process tests and observations are made, use Slide SH-26 to illustrate the Process of Troubleshooting for Gravity Thickeners.
4. "TROUBLESHOOTING OPERATIONAL PROBLEMS IN GRAVITY THICKENERS" *Most common problem:* Low sludge concentration	SLIDE SH-26 (word)

LESSON OUTLINE

Likely causes: Septic thickener pumping sludge at wrong rate
Corrections: Increase pumping, add chlorine, drain thickener

III. Dissolved Air Flotation Thickening (10 Minutes)

A. Air injection causes sludge flotation
Briefly discuss flow diagram with students

B. Normal Operations of Dissolved Air Flotation Thickeners

"FLOTATION UNITS NORMAL OPERATIONS"

- Feed system continuously
- Skim and remove floating sludge continuously
- Remove bottom sludge every 4 to 8 hours

C. Troubleshooting Air Flotation Thickening

1. "TESTS AND OBSERVATIONS FOR FLOTATION UNITS"
   - Observe float to determine air to solids ratio
   - Hydraulic loading
   - Solids loading
   - Float solids concentration
   - Subnatant solids concentration
   - Compute mass balance for unit

2. Common Problems in Flotation Units

a. "TROUBLESHOOTING AIR FLOTATION"
Problem: Low float solids concentration
Causes: Excessive skimming, excessive air/solids ratio
Corrections: Reduce skimmer speed, reduce air, increase solids load

KEY POINTS & INSTRUCTOR GUIDE

Refer class to Notebook page SH-8, Troubleshooting Guide for Gravity Thickeners.

Guide: Refer to Notebook page SH-9 Flotation Unit.

Guide: Use slide SH-27 to discuss normal operations.

SLIDE SH-27 (word)

Guide: Refer to Chart – Process of Troubleshooting in Student Notebook and at front of classroom. Illustrate use of troubleshooting process for air flotation thickening with Slide SH-28.

SLIDE SH-28 (word)

Use the next two slides to discuss troubleshooting common problems. Refer class to Notebook page SH-10, Troubleshooting Guide to Air Flotation.

SLIDE SH-29 (word)

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
b. "TROUBLESHOOTING AIR FLOTATION" *Problem:* Poor capture of solids *Causes:* Hydraulic or solids overload, Low air/solids ratio Low skimming rate *Corrections:* Increase air, increase skimming rate	SLIDE SH-30 (word)
IV. Centrifugation (10 Minutes) A. Uses rotation and centrifugal force to separate solids from liquid, thicken sludge. There are several types:	Guide: Refer to following diagrams in Student Notebook for Centerifuge units.
1. Rotating bowl centrifuge	Notebook page SH-11
2. Basket centrifuge	Notebook page SH-12
3. It is difficult to specify procedures to troubleshoot a centrifuge without knowing the exact design intent	
B. Normal Operation 1. If polymers are to be used, a jar test should be made to determine best apparent application and then field tested	Key Point: This is the same principle discussed in the lesson on Chemical Additions.
2. Some judgment should be made as to cost of chemicals vs capture and solids density 3. Centrifuge is started and sludge is then fed to the unit. Feed rate is increased to achieve desired results a. The lower the feed rate, the better the capture but % solids decreases b. A lower pool depth produces a drier cake, also less capture c. A high pool depth produces better capture and clarity of centrate	
d. A compromise between *b* and *c* normally produces the best all around results	Guide: Review these points of normal operation with class.
4. The amount of solids to be dewatered should be determined and then programmed into an operating schedule. Too often the operating schedule dictates the dewatering time	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
C. Process Evaluation for centrifuges 1. Normally, in the application of anaerobic sludge to a centrifuge, centrate quality is more significant than solid cake density	Guide: Note that there are some common elements in evaluating and troubleshooting centrifuges.
"TESTS AND OBSERVATIONS FOR CENTRIFUGES" • Solids volume to be dewatered • Capture rate compared to centrate quality • Polymer type and dosage	SLIDE SH-31 (word)
D. Troubleshooting Problems in Centrifuge Operations	Guide: Use the next four slides to discuss troubleshooting common centrifuge problems. Refer class to Student Notebook page SH-13 Troubleshooting Guide to Centrifugation.
1. "TROUBLESHOOTING CENTRIFUGES" *Problem:* Poor solids capture, cake density good *Causes:* Pool depth, feed rate, polymer type and dosage *Corrections:* Raise pool depth, lower feed rate if possible, change polymers	SLIDE SH-32 (word)
2. "TROUBLESHOOTING CENTRIFUGES" *Problem:* Good capture, low density cake *Causes:* Pool depth, polymer, bowl speed *Corrections:* Lower pool depth, vary polymer, increase bowl speed	SLIDE SH-33 (word)
3. "TROUBLESHOOTING CENTRIFUGES" *Problem:* Poor capture, low cake density, i.e., combination of first 2 problems *Corrections:* Lower feed rate Change polymer dosage Vary pool depth	SLIDE SH-34 (word)
4. "TROUBLESHOOTING CENTRIFUGES" *Problem:* Good capture, but insufficient capacity to handle daily load *Corrections:* Increase flow - Increase bowl speed - Increase aeration time - Add polymers	SLIDE SH-35 (word)

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
5. In summarizing this section, point out that in troubleshooting equipment like centrifuges, the troubleshooter may want to consult with others for help, including a. Other operators b. Manufacturer of the equipment c. Senior personnel in your agency d. EPA specialists	Key Point: Possible need for outside help. Refer to Chart, Process of Troubleshooting, Line 2e.
V. Aerobic Digestion (20 Minutes) A. Aerobic digesters are used, particularly in small plants, because they are simple to operate and not susceptible to upset	Guide: Refer to following diagrams in Student Notebook for Aerobic Digestion.
1. Aerobic digestion system	Refer to schematic diagram, Student Notebook page SH-14.
2. Typical aerobic digester	Notebook page SH-15.
B. Normal Operating Procedures 1. One advantage of aerobic digestion is that it is simple to operate, and not susceptible to upset 2. Sludge is introduced to the reactor on a continuous or hourly basis 3. Normally, some decanting facility is provided to thicken the digested sludge and return dense solids to the digester and supernatant liquor back to the system 4. Dissolved oxygen should be maintained between one and two milligrams per liter 5. Sludge can be concentrated to the extent where oxygen transfer is the limiting factor 6. Sludge is drawn off for dewatering as a function of ability to the extent where oxygen transfer is the limiting factor	Guide: Briefly review these procedures.
C. Illustration of aerobic digestion	Guide: Use the following 8 slides and slide key to illustrate and discuss aerobic digestion. Allow for class discussion and questions.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
Aerobic digestion is more common in small plants for reasons mentioned here; many anaerobic digesters have been converted because of operational problems. Items 3 and 5 do not apply in converted plants where the digester cover wasn't adequately opened or removed. The temperature rise makes a mess. Spring warmup operation in cold climates also makes a mess because aerobic digestion is negligible at low temperatures.	SLIDE SH-36
This view shows an 0.2 MGD plant with the clarifier in the center and aeration in a ring around it. *The aerobic digester* compartment is in the foreground. Sludge had been removed from this one occasionally to make a good operation.	SLIDE SH-37 Key Point: Emphasize the need for sludge removal.
This *aerobic digester* doesn't look so good. Scum disposal wasn't practiced. It just collected and was returned to the activated sludge aerator. The final clarifier was a mess because oil has a tendency to float solids if the oil concentration is high. At some oil concentration solids will neither float nor settle. This much scum usually means inadequate disposal of both scum and solids. the only way out is via the discharge.	SLIDE SH-38 Ask the class to try to identify the problem shown, and the causes.
Here is the surface of one *aerobic digester* in operation.	SLIDE SH-39 What's wrong???
This is the surface of the same *aerobic digester* after 2 hours of clarification for sludge disposal and supernating. The supernate in this case was exceptionally high in quality with less than 50 mg SS/liter. This can be done with good facilities, operation and maintenance. Scum and solids take-out for disposal instead of recycle makes a tremendous improvement in performance.	SLIDE SH-40
This is the air supply for the *aerobic digester* unit shown. The five blowers supply duplicate units. Two are adequate when weather is favorable for land disposal of solids; four have been used during spring warmup and extended wet weather.	SLIDE SH-41

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
Surface aeration is used in this installation. The level may be changed to vary turbine submergence and air supply, but it's still one unit with no standby capability. High MLSS, scum, and the disposal record indicated insufficient takeout.	SLIDE SH-42
When the sludge blanket is as close to the top as this view shows it to be after three hours of clarification, solids disposal is needed. The record showed regular burial of skimmings, but no sludge disposal in more than 2½ years since startup.	SLIDE SH-43
D. Troubleshooting Aerobic Digestion Problems	Guide: Use the next three slides to discuss troubleshooting problems with aerobic digestion. Refer class to Student Notebook page SH-16 Troubleshooting Guide to Aerobic Digestion.
1. "TROUBLESHOOTING AEROBIC DIGESTION" *Problem:* Low D.O. (below 1 mg/l) *Causes:* Insufficient air, heavy load *Corrections:* Increase air supply, unplug aeration, waste solids	SLIDE SH-44 (word)
2. "TROUBLESHOOTING AEROBIC DIGESTION" *Problem:* Excessive detergent foam *Causes:* Low solids in system *Corrections:* Increase solids by decanting and recycling solids If ineffective: may be due to industrial ABS detergents – eliminate or depress	SLIDE SH-45 (word)
3. "TROUBLESHOOTING AEROBIC DIGESTION" *Problem:* Thick, gelatenous foam *Causes:* High D.O. or excessive solids *Corrections:* Lower oxygen and/or solids input. In some digesters, this is normal, and not a problem.	SLIDE SH-46 (word)
VI. Sludge Drying Beds (10 Minutes)	
A. Description of facilities	Guide: Briefly describe drying beds (no diagram is provided).

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

1. Sludge drying beds are probably used more than any other method of sludge dewatering. They consist of a level area of sand, beneath which is a layer of gravel around and under drain system. Beds are divided into sections by thick concrete walls or wood planks, which vary in size from 10 to 25 feet wide and from 50 to 150 feet long. Both open and covered beds are used, but open beds are most common for obvious economic reasons.
2. Before sludge is applied, the bed should be relatively smooth and clean. This is the most common error made in operating drying beds. The surface of large beds should be given a slight grade away from the point where the sludge is introduced, so it will have a more uniform depth over the entire bed. In many instances where beds are made perfectly level, the sludge will be several inches thicker near the inlet.
3. There is considerable difference in opinion as to the best depth which sludge should be put on the drying beds. The best method for determining the proper depth is by trial and error. When sludge is initially applied to a bed, drainage is quite rapid. After the media is blinded, then the majority of water loss is by evaporation. Allow at least 4 inches for expansion of anaerobic sludge.

B. Normal operations of drying beds

1. Program draw offs over at least a six-month period.
    a. Compute sludge production
    b. Determine drying time at optimum depth
    c. Develop routine program for draw off and bed cleaning

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
2. Sludge draw off a. Never draw sludge on a dirty bed b. Never draw off to excessive depths: 1. Usually eight inches is a standard depth 2. Actual depth should be determined experimentally for optimum drying time	Guide: Discuss normal operations by using the next slide, which summarizes this section.
3. Sludge bed cleaning a. Removal should be accomplished when sludge is well cracked (30-40% solids) b. After removal bed should be raked level and new sand applied if necessary	
"SLUDGE DRYING BEDS – NORMAL OPERATIONS" • Compute and program draw offs • Draw sludge off Only on to a clean bed Not to excessive depth (8 in. normal) • Bed cleaning Remove when sludge is well cracked (30-40% solids) Rake level and apply new sand	SLIDE SH-47 (word)
C. Process Evaluation for Drying Beds	Use slide SH-48 to illustrate process control measures.
"DRYING BEDS – PROCESS EVALUATION" • Compare sludge production to area available • Use records and log to determine actual sludge application actual drying time sand replacement	SLIDE SH-48 (word)
D. Common problems to troubleshoot with sludge drying beds 1. The most common and serious problem is excessive dewatering time	
"CAUSES OF EXCESSIVE DEWATERING TIME ON SLUDGE DRYING BEDS"	SLIDE SH-49 (word)

LESSON OVERVIEW

- Overload of sludge
- Application on uncleaned bed
- Dirty sand on bed
- Plugged underdrain system
- Weather conditions
- Septic sludge
- Wrong chemical dose

VII. Vacuum Filtration (10 Minutes)

A. Vacuum filtration is one of the mechanical means of sludge dewatering

B. Normal operations of a vacuum filter

"VACUUM FILTERS – NORMAL OPERATIONS"

- Sludge is fed continuously
- Sludge is chemically conditioned continuously
- Operate filter drum at optimum speed to get thick cake to drop off to conveyor
- Most systems operate well with proper chemicals and filter media

C. "PROCESS EVALUATION FOR VACUUM FILTERS"

Tests and Observations to make

- Solids loading
- Cake concentration
- Filtrate concentration
- Chemical dosages
- Dewaterability at applied dosage
- Filter cloth condition

D. Troubleshooting operational problems in vacuum filters

1. "TROUBLESHOOTING VACUUM FILTERS"

Problem: Thin cake, poorly dewatered

Causes: Blind cloth, chemical dosage, vacuum, speed

Corrections: Clean cloth, determine proper chemical dose, overhall vacuum pump and lines

KEY POINTS & INSTRUCTOR GUIDE

Refer students to Student Notebook page SH-17 for corrections to these problems. Briefly discuss.

Refer to diagrams, Student Notebook, page SH-18.

Use Slide SH-50 to discuss normal operations.

SLIDE SH-50 (word)

SLIDE SH-51 (word)

Use Slides SH-52 and SH-53 to discuss troubleshooting vacuum filters.

SLIDE SH-52 (word)

LESSON OUTLINE

2. "TROUBLESHOOTING VACUUM FILTERS"

   Problem: Thick cake, poorly dewatered

   Causes: High drum speed, high feed rate, low vacuum

   Corrections: Lower drum speed, check and repair vacuum system, reduce feed rate

VIII. Summary and Questions (10 Minutes)

A. Summarize Lesson

1. "METHODS OF SOLIDS HANDLING"

Thickening	Gravity Thickening Flotation Centrifugation
Stabilization	Aerobic Digestion
Dewatering	Sludge Drying Beds Vacuum Filtration

2. "PRINCIPAL PROBLEMS IN SLUDGE HANDLING"
   - Low sludge concentration
   - Poor capture of solids
   - Septicity
   - Poor dewatering
   - Final disposal and the problems it creates

B. Questions and Discussions

KEY POINTS & INSTRUCTOR GUIDE

SLIDE SH-53 (word)

Guide: Use Slide SH-54 to summarize topics covered.

SLIDE SH-54 (word)

Guide: From a troubleshooting perspective, the following problems are important.

SLIDE SH-55 (word)

For additional information, refer students to EPA Manual "Sludge Treatment and Disposal."

Guide: Use remaining time for questions and discussions.

SUPPLEMENTAL INFORMATION ON SOLIDS HANDLING PROCESSES

for Instructor's Use and Background

A. *Gravity Thickeners* – Process Application, Parameters and Anticipated Performance

1. Primary Sludge
    a. Hydraulic loading, approximately 1,500 gal/ft^2/day
    b. Solids loading, 15-30 lbs/ft^2/day
    c. Underflow concentration, 6.5 – 8.0%
    d. Supernatant concentration, approximately equal to raw sewage

2. Primary and Trickling Filter Sludge
    a. Hydraulic loading approximately 1,000 gal/ft^2/day
    b. Solids loading 10-20 lbs/ft^2/day
    c. Underflow concentration 5.5 – 7.5%
    d. Supernatant concentration approximately equal to raw sewage

3. Activated Sludge
    a. Hydraulic loading approximately 1,500 gal/ft^2/day
    b. Solids loading, 4-8 lb solids/ft/day
    c. Underflow concentration, 2 – 3%
    d. Supernatant concentration, 50-150 mg/l suspended solids

4. Primary and Activated Sludge
    a. Hydraulic loading approximately 1,000 gal/ft^2/day
    b. Solids loading 8-15 lbs/ft^2/day
    c. Underflow concentration 2.5 – 5%
    d. Supernatant concentration approximately equal to raw sewage

5. Observe surface for gas bubbles

6. Observe system for odor

7. Determine the average underflow solids concentration

8. Determine the average overflow solid concentration

B. *Dissolved Air Flotation* – Process Application, Parameters and Anticipated Performance

1. Primary sludge thickening
    a. Hydraulic loading, 1,000-2,500 gal/ft^2/day
    b. Solids loading, 50 lbs/ft^2/day
    c. Float solids concentration, 6 – 8%
    d. Subnatant solids concentration – equal to raw sewage

2. Activated Sludge Thickening
    a. Hydraulic loading, approximately 2,000 gal/ft² /day
    b. Solids loading, 10-15 lbs/ft² /day
    c. Float solids concentration, 3 – 4% (3.5 – 5% with polymers)
    d. Subnatant solids concentration – 50-200 mg/l suspended solids

3. Primary and Waste Activated Sludge Thickening
    a. Hydraulic loading – approximately 2,000 gal/ft² /day
    b. Solids loading, 15-30 lbs/ft² /day
    c. Float solids concentration, 5 – 7%
    d. Subnatant solids concentration – approximately equal to raw sewage

4. Normal Operating Procedures
    a. Systems are usually fed continuously
    b. Float is skimmed continuously while being fed
    c. Bottom sludge accumulations removed every 4 to 8 hours
    d. Air to solids ratio checked daily by visual observation of float
        1. If float is excessively frothy air injection rate is reduced.
        2. If excessive solids are accumulating on the bottom, air injection rate is increased. If too much agitation, decrease.

C. *Sludge Centrifugation* – Process Application, Parameters and Anticipated Performance

1. Raw Primary Sludge
    a. Capture, 80 – 90%
    b. Solids, 25 – 30%
    c. Chemicals, not normally utilized

2. Anaerobically Digested Sludge
    a. Capture, 70 – 95%
    b. Solids, 15 – 25%
    c. Chemicals, polymers 0.05 – 3%

3. Aerobically Digested Sludge
    a. Capture, 70 – 95%
    b. Solids, 15 – 20%
    c. Chemicals, polymer 0.05 – 2%

4. General
    a. Most centrifuges are of the solid bowl type
        1. Cylindrical solid bowl gives good capture
        2. Conical solid bowl renders a good dense sludge
        3. A combination of the above renders a compromise between the two units

D. *Aerobic Digestion* – Process Application, Parameters and Anticipated Performance

1. Application
    a. Primarily used on waste activated sludge
    b. Most common application is on small treatment plants, less than 1 MGD or where technical competence is lacking
2. Waste Activated Sludge
    a. Detention time 10-15 days
    b. Solids loading 0.1-2.0 lbs of volatile matter per cubic foot per day
    c. Anticipated volatile solids reduction, 60%
3. Primary and Waste Activated Sludge
    a. Hydraulic detention time 15-25 days
    b. Solids loading 0.1-0.2 lbs of volatile matter per cubic foot per day

E. *Sludge Drying Beds* – Process Application, Parameters and Anticipated Performance

1. Anaerobically Digested Sludge
    a. Area required 1.0 to 3.0 ft^2 per capita
    b. Average depth 6 to 18 inches
    c. Average drying 1 to 6 weeks
2. Aerobically Digested Sludge
    a. Area required 1.0 to 2.0 ft^2 per capita
    b. Average depth 8-18 inches
    c. Average drying 1-4 weeks
3. General Configuration
    a. Should have under drain system
    b. Beds should be designed for easy cleaning
    c. Size for average draw off

F. *Vacuum Filtration* – Process Application, Parameters and Anticipated Performance

1. Primary Sludge Dewatering
    a. Loading + Yield, 4-10 lbs/ft^2/hr
    b. Feed concentration 5 – 10%
    c. Cake solids concentration 20 – 35%
2. Primary and Waste Activated Sludge
    a. Loading and Yield, 3-5 lbs/ft^2/hr
    b. Feed concentration, 3 – 6%
    c. Cake solids concentration, 15 – 25%
3. Anaerobically Digested Sludge
    a. Loading and Yield, 3-8 lbs/ft^2/hr
    b. Feed concentration 3 – 5%
    c. Cake solids concentration 15 – 25%
4. Most common chemicals used in pre-conditioning
    a. Lime (CaO or CaOH) (5 – 15%)
    b. Ferric Chloride (FeCl) (2 – 10%)
    c. Polymer (0.3 – 2.5%) usually cationic

LESSON PLAN – SUBDIVISION 4 **TIME: 40 Minutes**

Title: Tall Tales - or "Where Did All That Sludge Come From?"

Instructor Objectives: To involve students in discussing a variety of solids handling problems which they have encountered at wastewater treatment facilities. To stimulate student participation and discussion of *their own* experiences.

Student Objectives: As a result of this lesson subdivision, students will be able to do the following:

1. Identify actual solids handling operational problems that have occurred in the region where the course is being presented
2. Specify actual approaches to local solids handling problems
3. Have an opportunity to recommend alternative approaches to solids handling processes

Training Materials:

No special instructional materials are required for this lesson subdivision. The instructor should make reference to the Process of Troubleshooting Chart at appropriate times.

Students should be provided with cards on which to submit descriptions of problems

Classroom Set-up:

A normal classroom set-up will be required. Students should be seated with their student groups.

Chalkboard or easel

Subdivision Schedule:

Within the 40 minute time period, the following schedule should be observed:

TIME	ACTIVITY
10 minutes prior to start of lesson	Students provide written description of solids handling problems
0-30 minutes during lesson	Instructor and students discuss several solids handling problems provided by students. Each problem discussed may take from 10 to 15 minutes

Subdivision Approach:

The overall approach of this subdivision is to involve the students by –

a. Providing problems for discussion in writing
b. Discussing problems they have encountered in solids handling
c. Allowing the class opportunity to provide alternative approaches to problems being discussed

1. Prior to this subdivision, earlier in the lesson, the instructor should take 10 minutes to have students fill out cards provided to them. Ask each student to provide a written description of one or two of the most extreme, most ludicrous sludge problems they have encountered.

   Their description should contain –
   a. the location and nature of the problem
   b. the type of plant
   c. any important circumstances pertaining to the problem
   d. how it was handled and solved (if it was!)

2. Before the actual lesson subdivision begins, the instructor should screen the cards and select the most interesting problems for discussion

3. During the lesson, the instructor leads the class in discussion of the problems selected. Discussion should occur in the following sequence –
   a. Instructor reads the problem selected
   b. Student submitting problem discusses it
   c. Discussion of problem by the class takes place
   d. Class is asked to suggest alternative approaches to the problem

4. Following discussion, instructor selects another problem and repeats step 3

   Specific instructor activities are indicated in the following lesson outline.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
I. Students Provide Problems (10 Minutes) A. Distribute cards to students (or include them in their Notebook materials distributed earlier). B. Instruct students to fill out cards by describing one or two of the most extreme, most ludicrous sludge problems they have encountered. Each description should contain: 1. Location of the problem 2. Nature of the problem 3. The type of plant 4. Circumstances relating to the problem 5. How the problem was handled and solved C. Collect the cards after 10 minutes	This activity takes place prior to the beginning of this subdivision, earlier in the lesson.
II. Instructor screens cards A. Screen all cards submitted B. Put them in order of priority of interest in the problems provided	This takes place prior to the start of this subdivision.
III. Class Discussion of Problems (30 Minutes) A. Read first problem selected B. Ask student submitting the problem to briefly discuss it C. Allow for class questions, full discussion of problem D. Toward end of discussion, ask class to suggest alternative approaches to the problem E. Folowing discussion, select another problem and repeat Steps A-D.	Guide: Instructor is to serve as discussion *leader* allowing students full participation.

SOLIDS HANDLING

LESSON PLAN – SUBDIVISION 5 **TIME: 40 MINUTES**

Title: Applying the Process of Troubleshooting

Instructor Objectives: To provide a case study in solids handling (vacuum filtration) to enable the class to use the Process of Troubleshooting to attempt to solve an actual problem. To play the role of "operator" in relation to the student "troubleshooters." To summarize the lesson on Solids Handling.

Student Objectives: As a result of this lesson subdivision, students will be able to do the following:

1. Analyze and troubleshoot a specific problem in vacuum filtration that affects overall treatment plant performance
2. Apply the Process of Troubleshooting to a large scale treatment plant problem, and identify, analyze and attempt to correct such a problem
3. See and discuss the connection between proper solids handling and overall treatment plant performance

Training Materials:

Process of Troubleshooting Chart

Classroom Set-up:

A normal classroom set-up will be required. Students should be seated with their student groups

Chalkboard or easel

Pointer

Subdivision Schedule:

Within the 40 minute time period, the following schedule should be observed

TIME	ACTIVITY
0-25 minutes (time may be flexible depending on the degree of discussion on the problem)	Troubleshooting problem presented by instructor
25-40 minutes	Summary of lesson

Subdivision Approach:

1. The instructor is to present an actual case-study problem to the class in stages. After each stage is presented, the students are to use elements from the Process of Troubleshooting to question the instructor — who is to take the role of plant "operator" in the exercise.

2. Once the students identify what's happening in a given stage, the instructor presents the next stage, until the problem is complete and discussion is finished.

3. Following discussion of the problem, the instructor briefly summarizes the entire Solids Handling lesson. The remaining time should be used to answer questions and receive student comments on troubleshooting Solids Handling.

LESSON OUTLINE

I. Case Study Problem for class to analyze utilizing the Process of Troubleshooting (25 Minutes)

   A. This problem is drawn from an actual case that occurred in California in 1974.

   B. First Stage of Problem

      1. Operator (instructor reads to class)

         "I'm the chief operator of a 10 MGF activated sludge plant. We never had any big problems until now. The plant incinerates sludge. The primary and waste activated sludge is dewatered with a vacuum filtration system."

         "I'm sure glad the state sent you out here. Until recently everything was O.K. Last week I noticed bulking of my sludge, and the BOD in the effluent went way up. Now the whole activated sludge system seems to have gone to pot. The effluent is black, it smells like H--, and the solids are up over 100 mg/l."

      2. Have class attempt to "troubleshoot" by asking questions of the "operator." The instructor should answer questions in accord with the information provided below.

      3. After discussion of the situation, present the next stage of information about the problem.

   C. Second Stage of Problem

      1. Operator (read to class)

         "About a half year ago, we replace the media on the vacuum filter with a new type of media. We didn't have time to run any leaf tests to see how the sludge dewatered. What happened was we got less yield rate and a higher moisture content in our sludge. Finally, the filter runs took so long that we needed to put on an extra shift. Not only that, but our fuel cost went up 350%!"

KEY POINTS & INSTRUCTOR GUIDE

Guide: Instructor presents this problem to the class in the role of "plant operator." The class should approach the problem as the "troubleshooters."

LESSON OUTLINE

2. Have class use the steps in the Process of Troubleshooting to advise the operator on what he should have done at that time.
3. After discussion, present the next stage of information about the problem.

D. Third Stage of Problem

1. Operator (read to class)

   "The boss said the costs were getting too high, so, in a couple of months we shut down the extra shift. This meant that only half of our sludge was being dewatered. The rest? Well, we kept it in the gravity thickener. It became septic, and a thin, liquified sludge developed there, so we pumped it back to the primary clarifier. Wouldn't you? Well, before too long the primary turned septic from the overload. Finally, the activated sludge tanks got overloaded from all of the primary effluent. What a mess!"

2. Have class advise the operator on what he should have done at that time.
3. After discussion, present the final stage of information about the problem.

E. Final Stage of Problem

1. Operator (read to class)

   "Well, that's it. Now you're here to help me turn this around. Since the activated sludge system worked so well in the past, we didn't try to change anything this time. No, we didn't increase the air, or try to increase the cell mass in the system. I know, now we have bulking, lousy BOD removal, and would you believe that we have 10 mg/l of sulfide in the final effluent? Our tertiary filters are plugged. The whole plant is damn near dead! Help!!"

2. Have class advise operator on what to do at this point.

KEY POINTS & INSTRUCTOR GUIDE

Key Point: Stress the use of steps in the Process of Troubleshooting.

STUDENT NOTEBOOK MATERIALS

The following materials are included in Section II of the Student Notebook, Solids Handling. The Notebook is distributed to students at the start of the course, and is available to them as a reference material throughout the course. Some of these materials are to be used by the instructor as an integral part of the lesson.

Index of Notebook Materials

Pages	Material	Use in Lesson
SH – 1 thru SH – 3	Process diagrams, anaerobic digestion	Reference by instructor, Subdivision 1
SH – 4	Start-up Procedure for Digesters	Same as above
SH – 5	Chart – Sludge Treatment Processes	Reference by instructor Subdivision 3, Section I
SH – 6	Chart – Unit Processes, Sludge Processing and Disposal	Same as above
SH – 7	Process diagram, Gravity Thickener	Reference by instructor Subdivision 3, Section II
SH – 8	Troubleshooting Guide, Gravity Thickeners	Same as above
SH – 9	Process diagram, Flotation Unit	Reference by instructor Subdivision 3, Section III
SH – 10	Troubleshooting Guide, Dissolved Air Flotation Thickening	Same as above
SH – 11 & SH – 12	Process diagrams, Centrifuges	Reference by instructor Subdivision 3, Section IV
SH – 13	Troubleshooting Guide, Sludge Centrifugation	Same as above
SH – 14 & SH – 15	Process diagrams, Aerobic Digestion	Reference by instructor Subdivision 3, Section V
SH – 16	Troubleshooting Guide, Aerobic Digestion	Same as above
SH – 17	Troubleshooting Guide, Sludge Drying Beds	Reference by instructor Subdivision 3, Section VI
SH – 18	Process diagrams, Vacuum Filters	Reference by instructor Subdivision 3, Section VII
SH – 19	Troubleshooting Guide, Vacuum Filtration	Same as above
SH – 20	References	

LESSON OUTLINE

F. Analysis of Problem

1. Have class discuss the key points illustrated in this problem, which are

    a. The entire plant failed because of an arbitrary decision to make one slight change in the sludge dewatering system.

    b. That decision could have been avoided by testing the sludge dewatering properties using a leaf test.

    c. Once the sludge handling system failed, the primary and secondary systems were not controlled to adjust to the changes. While it may have been too late to avoid the problem, the disastrous consequences could have been avoided with some smart process controls.

II. Summary and Questions (15 Minutes)

Use the remaining time to –

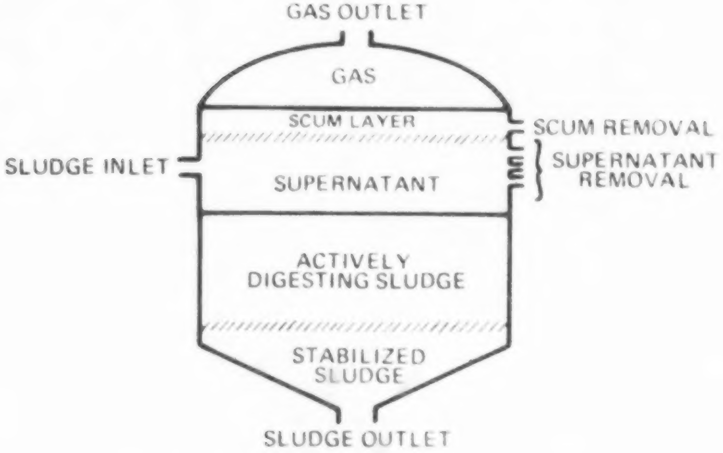
A. Briefly summarize the Solids Handling Lesson

B. Take questions and comments

KEY POINTS & INSTRUCTOR GUIDE

Guide: These are the key points of this problem, and should be stressed.

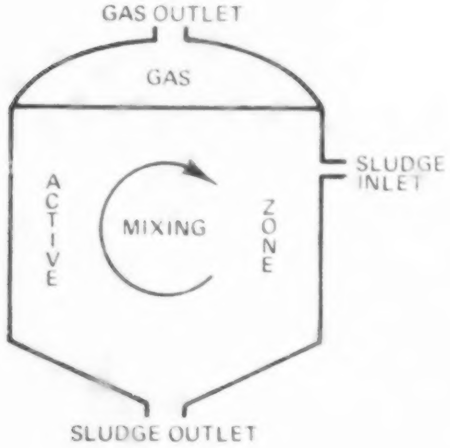
Reproduced from EPA Manual "Sludge Treatment and Disposal".


GAS OUTLET
GAS
SCUM LAYER
SCUM REMOVAL
SLUDGE INLET
SUPERNATANT
SUPERNATANT REMOVAL
ACTIVELY DIGESTING SLUDGE
STABILIZED SLUDGE
SLUDGE OUTLET

(A)

STANDARD RATE DIGESTION

1. UNHEATED
2. DETENTION TIME 30 – 60 DAYS
3. LOADING 0.03 – 0.10 lb. VSS/cu. ft./day
4. INTERMITTENT FEEDING AND WITHDRAWAL
5. STRATIFICATION

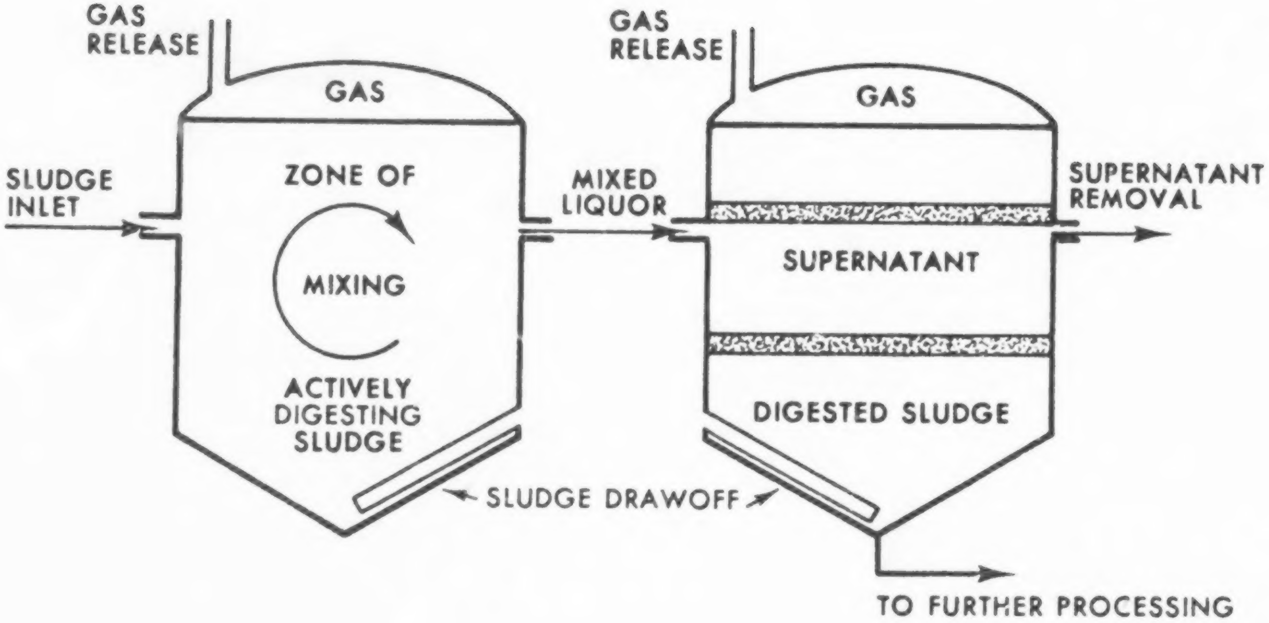

GAS OUTLET
GAS
SLUDGE INLET
ACTIVE
MIXING
ZONE
SLUDGE OUTLET

(B)

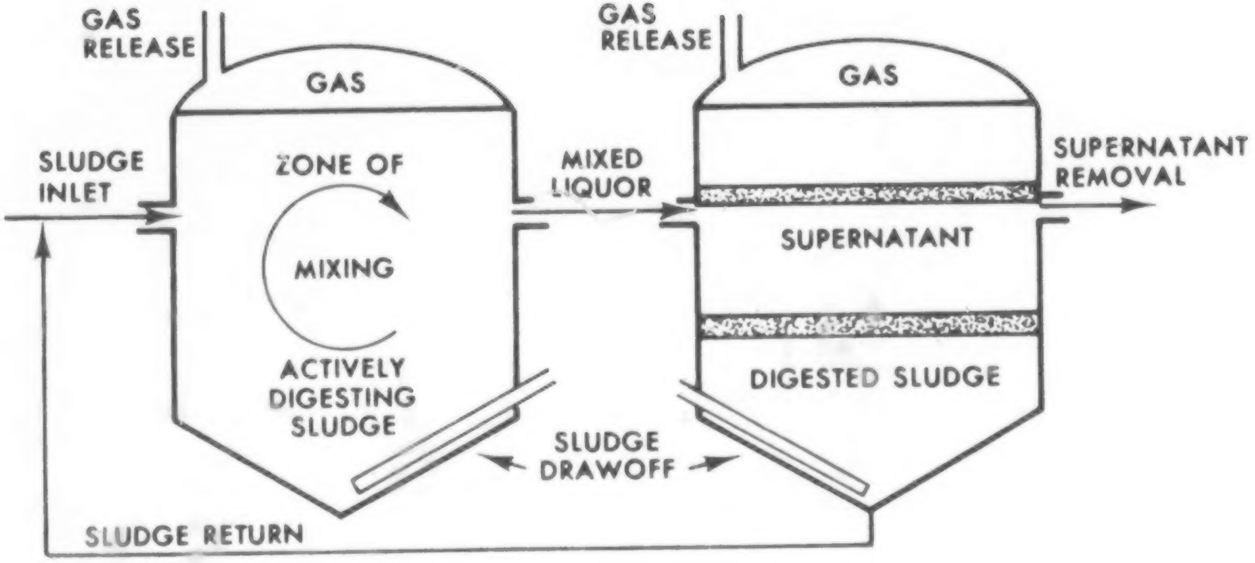
HIGH RATE DIGESTION

1. HEATED TO 85° – 95° F
2. DETENTION TIME 15 DAYS OR LESS
3. LOADING 0.10 – 0.50 lb. VSS/cu. ft./day
4. CONTINUOUS OR INTERMITTENT FEEDING AND WITHDRAWAL
5. HOMOGENEITY

STANDARD RATE AND HIGH RATE DIGESTION


GAS RELEASE
GAS
SLUDGE INLET
ZONE OF
MIXING
ACTIVELY DIGESTING SLUDGE
SLUDGE DRAWOFF
MIXED LIQUOR
GAS RELEASE
GAS
SUPERNATANT REMOVAL
SUPERNATANT
DIGESTED SLUDGE
TO FURTHER PROCESSING

TWO-STAGE ANAEROBIC DIGESTION


GAS RELEASE
GAS
SLUDGE INLET
ZONE OF
MIXING
ACTIVELY DIGESTING SLUDGE
MIXED LIQUOR
GAS RELEASE
GAS
SUPERNATANT REMOVAL
SUPERNATANT
DIGESTED SLUDGE
SLUDGE DRAWOFF
SLUDGE RETURN

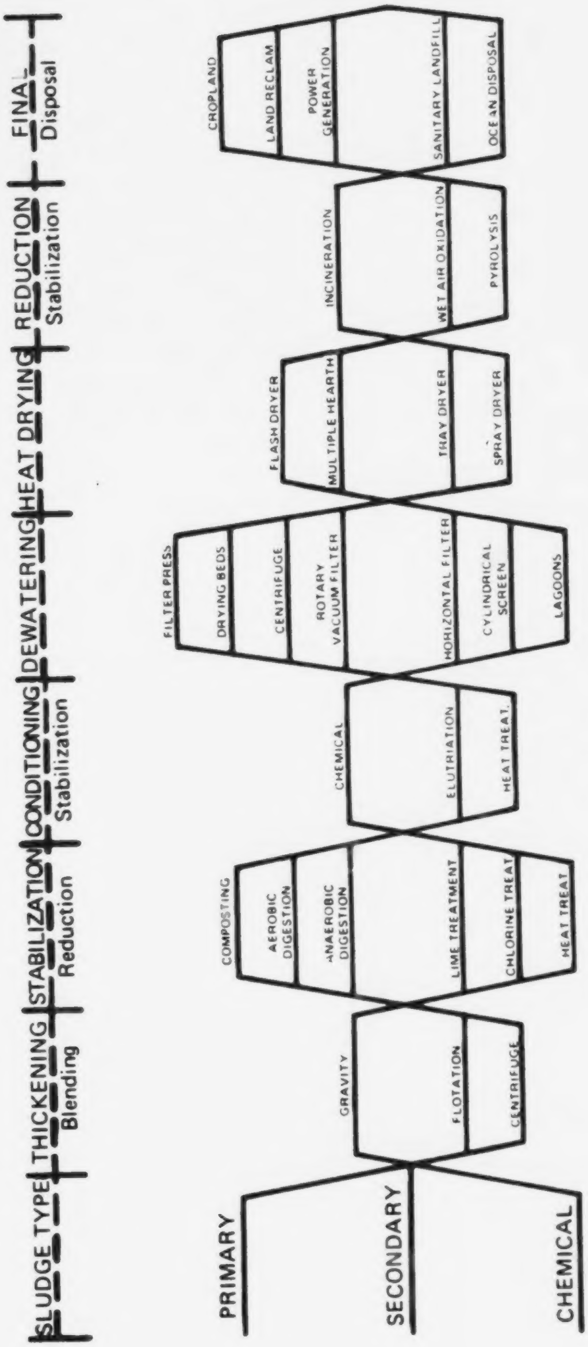
ANAEROBIC CONTACT DIGESTION

START UP PROCEDURE FOR DIGESTERS

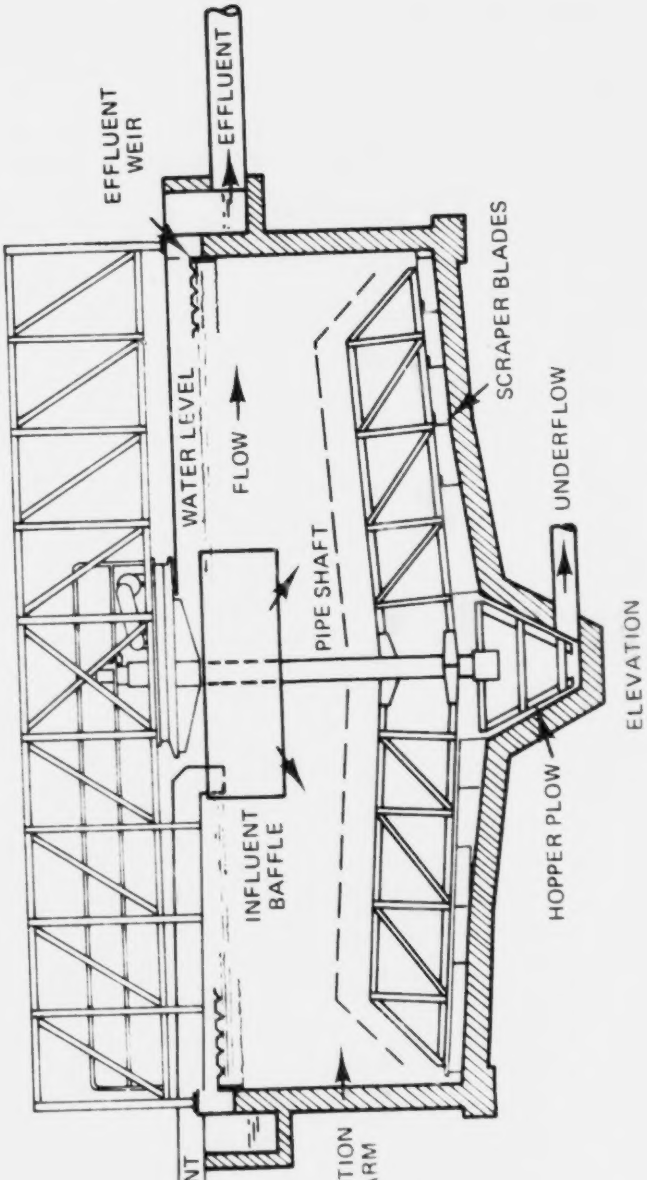
1. Fill with raw sewage
2. Heat to desired temperature (approx. 95°F)
3. Feed digester at 0.01 lb of VM/ft^3/day
4. Compute volatile acids, alkalinity, plus pH daily
5. Buffer the system with lime or sodium carbonate
6. Plot volatile acid concentration as a function of time
7. Mix digester continuously if possible and maintain constant temperature
8. As soon as volatile acid concentration starts to drop rapidly increase loading by 0.01 lbs of VM/ft^3/day
9. Continue until full load is on system
10. Seed sludge can be added to accelerate the start up process provided it can be added in sufficient quantity (10% of tank volume) and not be cooled or aerated in the transfer process

UNIT PROCESSES	FUNCTIONS
Thickening (Blending)	– Water Removal – Volume Reduction – Post Process Efficiencies – Blending
Stabilization (Reduction)	– Pathogen Destruction – Volume and Weight Reduction – Odor Control – Putrescibility Control – Gas Production
Conditioning (Stabilization)	– Improve Dewatering or Thickening Rate – Improve Solids Capture – Improve Compactability – Stabilization
Dewatering	– Water Removal – Volume and Weight Reduction – Change to Damp Cake – Reduces Fuel Requirements for Incineration/Drying
Heat Drying	– Water Removal – Sterilization – Utilization
Reduction (Stabilization)	– Destruction of Solids – Water Removal – Conversion – Sterilization
Final Disposal	– Utilization (Cropland) – Utilization (Energy) – Utilization (Land Reclamation) – Disposal (Landfill) – Disposal (Ocean)

SLUDGE TREATMENT PROCESSES


SLUDGE TYPE
THICKENING
Blending
STABILIZATION
Reduction
CONDITIONING
Stabilization
DEWATERING
HEAT DRYING
REDUCTION
Stabilization
FINAL
Disposal
PRIMARY
SECONDARY
CHEMICAL
GRAVITY
FLOTATION
CENTRIFUGE
COMPOSTING
AEROBIC DIGESTION
ANAEROBIC DIGESTION
LIME TREATMENT
CHLORINE TREAT
HEAT TREAT
CHEMICAL
ELUTRIATION
HEAT TREAT.
FILTER PRESS
DRYING BEDS
CENTRIFUGE
ROTARY VACUUM FILTER
HORIZONTAL FILTER
CYLINDRICAL SCREEN
LAGOONS
FLASH DRYER
MULTIPLE HEARTH
TRAY DRYER
SPRAY DRYER
INCINERATION
WET AIR OXIDATION
PYROLYSIS
CROPLAND
LAND RECLAM
POWER GENERATION
SANITARY LANDFILL
OCEAN DISPOSAL

UNIT PROCESSES – SLUDGE PROCESSING AND DISPOSAL


EFFLUENT WEIR
EFFLUENT
WATER LEVEL
FLOW
SCRAPER BLADES
PIPE SHAFT
UNDERFLOW
ELEVATION
HOPPER PLOW
INFLUENT BAFFLE
RAISED POSITION OF TRUSS ARM
INFLUENT

Courtesy Link Belt

GRAVITY THICKENER

TROUBLESHOOTING GUIDE – SOLIDS HANDLING

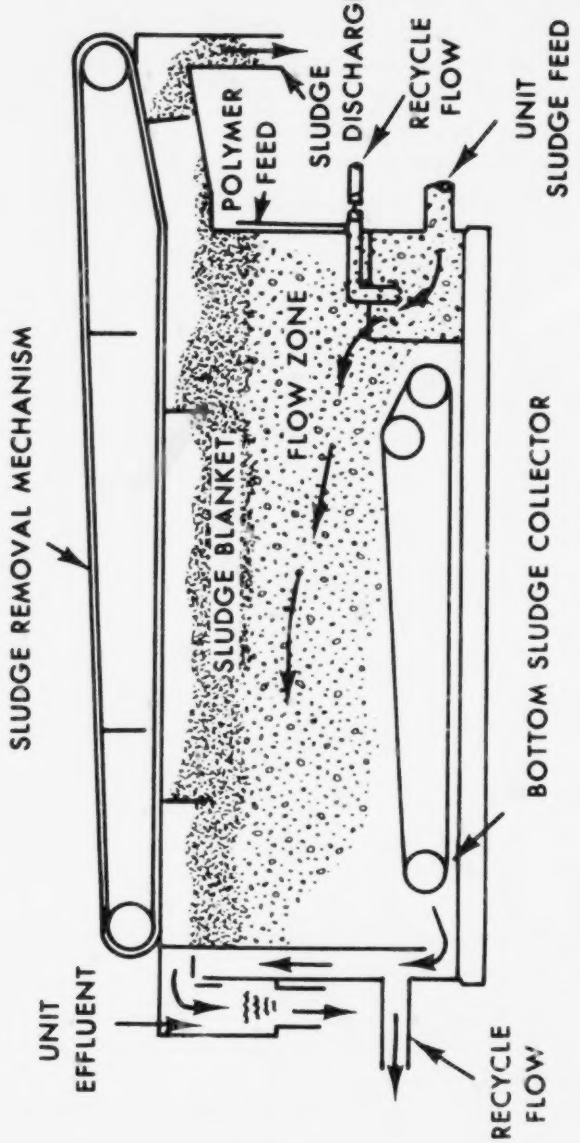
I. GRAVITY THICKENERS

A. Process Evaluation Measures

1. Determine the hydraulic loading
2. Determine the solids loading
3. Compute a mass balance around the system
4. Determine the IOD of the system (Immediate Oxygen Demand)

B. Problem Identification and Correction

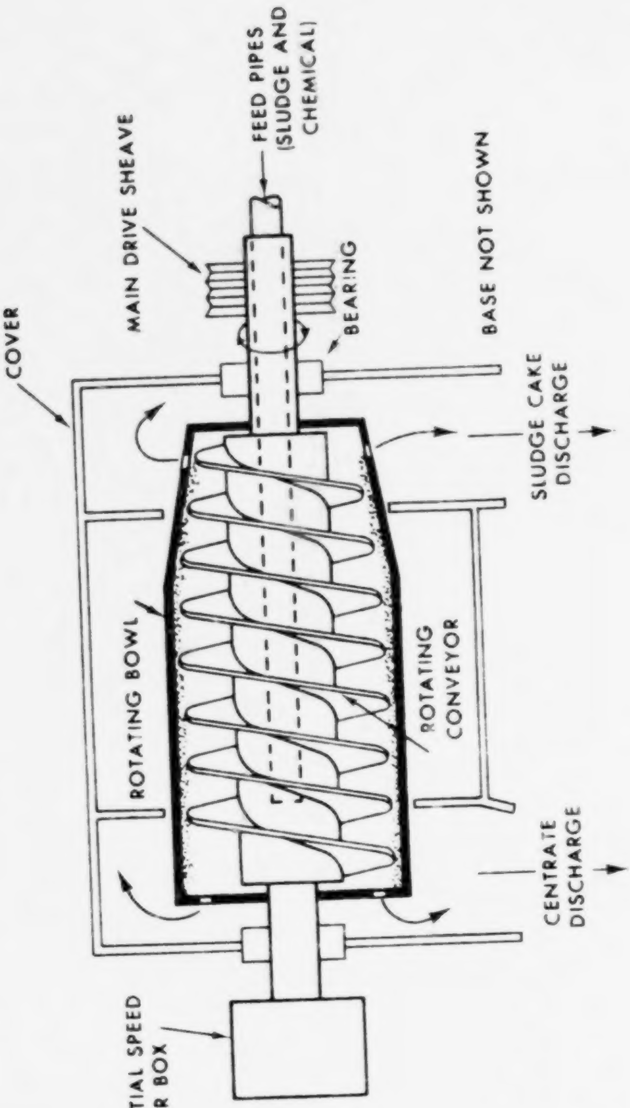
1. Low thickened sludge concentration
    a. Possible cause – over pumping of thickened sludge, or pumping at improper rate
        1. Characterized by:
            a. Hydraulic and solids loading, normal
            b. Mass balance, normal
            c. Supernatant within specs, low IOD, solids, normal
            d. No odor
            e. No gas bubbles
        2. Corrective measure:
            a. Modify sludge pumping rate from thickener by computing required rate
    b. Possible cause – thickener becomes septic
        1. Characterized by:
            a. Odor from thickener
            b. High IOD in supernatant
            c. High solids in supernatant
            d. Septic liquified thickened sludge
            e. High volatile acid concentration in thickened sludge (73,000 mg/l)
        2. Corrective measures
            a. Increase sludge pumping
            b. Add chlorine
            c. Drain thickener contents, to digester wash down and start over again
            d. The above corrective measures should be attempted in sequence where (c) is the most drastic measure
            e. Check pumps, valves
            f. Reduce possible overloading of tank
            g. Add air 1 to 2 feet below surface, or in wet well
            h. Recycle up to hydraulic load capacity


SLUDGE REMOVAL MECHANISM
SLUDGE BLANKET
FLOW ZONE
BOTTOM SLUDGE COLLECTOR
POLYMER FEED
SLUDGE DISCHARGE
RECYCLE FLOW
UNIT SLUDGE FEED
UNIT EFFLUENT
RECYCLE FLOW

FLOTATION UNIT

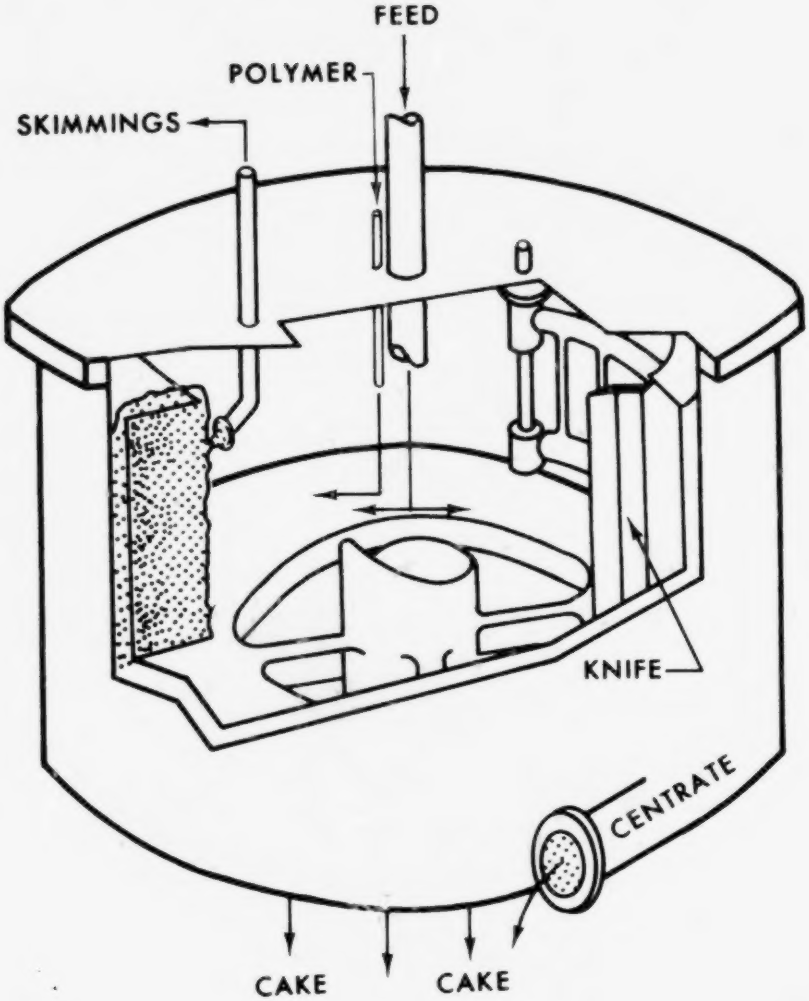
TROUBLESHOOTING GUIDE – SOLIDS HANDLING

II. DISSOLVED AIR FLOTATION THICKENING
  A. Process Evaluation Measures
    1. Determine hydraulic loading
    2. Determine solids loading
    3. Determine average float solids concentration
    4. Determine average subnatant solids concentration
    5. Compute mass balance around the system
  B. Problem Identification and Correction
    1. Low float solids concentration
      a. Possible cause – excessive skimming
        1. Characterized by:
          a. hydraulic loading – normal
          b. Solids loading – normal
          c. Float OK – not frothy due to excessive air
          d. Air to solids ratio – normal
        2. Corrective measures – reduce skimmer speed to maximum thickness without having excessive solids carry over.
      b. Possible cause – excessive air/solids ratio
        1. Characterized by:
          a. Hydraulic loading, OK
          b. Solids loading, OK
          c. Float extremely frothy
        2. Corrective measures
          a. Reduce air to pressurization system, or
          b. Increase solids load to thickener
          c. Obtain recycle rate of 1:1 to 3:1
    2. Poor Capture
      a. Possible causes –
        1. Hydraulically overloaded
        2. High solids loading
        3. Low A/S ratio
        4. Low removal or skimming rate
        5. Poor rise rate
      b. Hydraulic or solids overload
        1. Check first, if satisfactory then check
      c. A/S solids loading
        1. Check, characterized by poor float formation solids settling to the bottom. If normal, then check
      d. Skimming rate
        1. Characterized by good thick float, but excessively deep to the point where it is coming up under the baffle if rate is too low. If normal, then check
      e. Poor rise rate
        1. Characterized by high sludge volume index, poor float density, and dispersed floc



DIFFERENTIAL SPEED GEAR BOX
COVER
ROTATING BOWL
MAIN DRIVE SHEAVE
FEED PIPES (SLUDGE AND CHEMICAL)
BEARING
BASE NOT SHOWN
ROTATING CONVEYOR
CENTRATE DISCHARGE
SLUDGE CAKE DISCHARGE

SOLID BOWL CENTRIFUGE
WITH CONVEYOR DISCHARGE AND CONTINUOUS COUNTERCURRENT


FEED
POLYMER
SKIMMINGS
KNIFE
CENTRATE
CAKE
CAKE

BASKET CENTRIFUGE

TROUBLESHOOTING GUIDE – SOLIDS HANDLING

III. SLUDGE CENTRIFUGATION

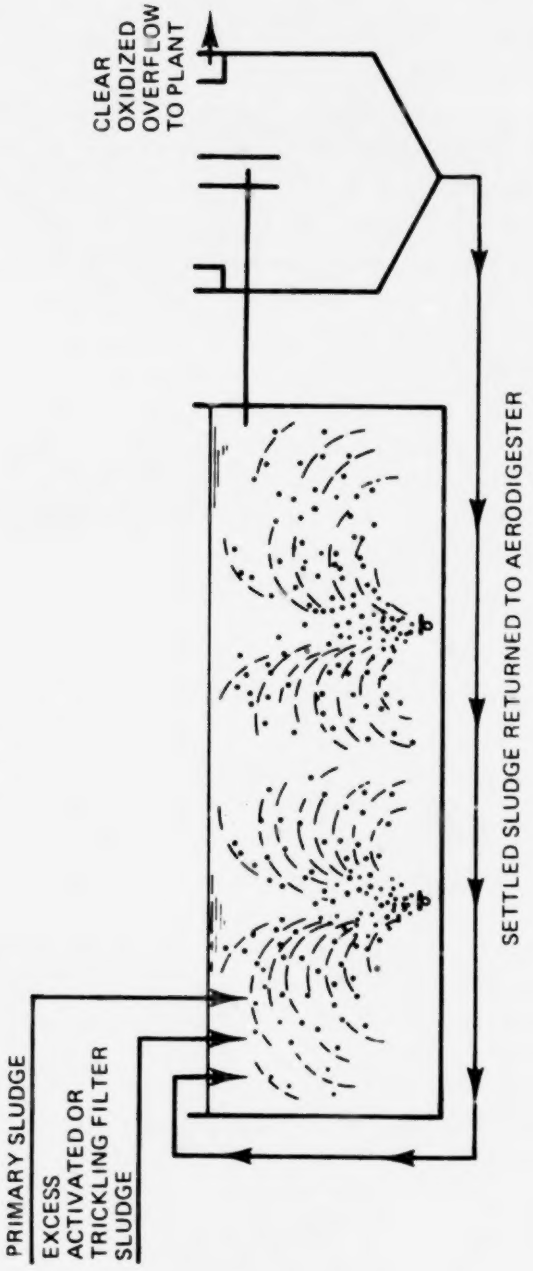
A. Process Evaluation Measures

NOTE: It is not possible to give exact procedures as to process evaluation without knowing the exact design intent. Normally in anaerobic sludge centrate quality is more significant than solid cake density.

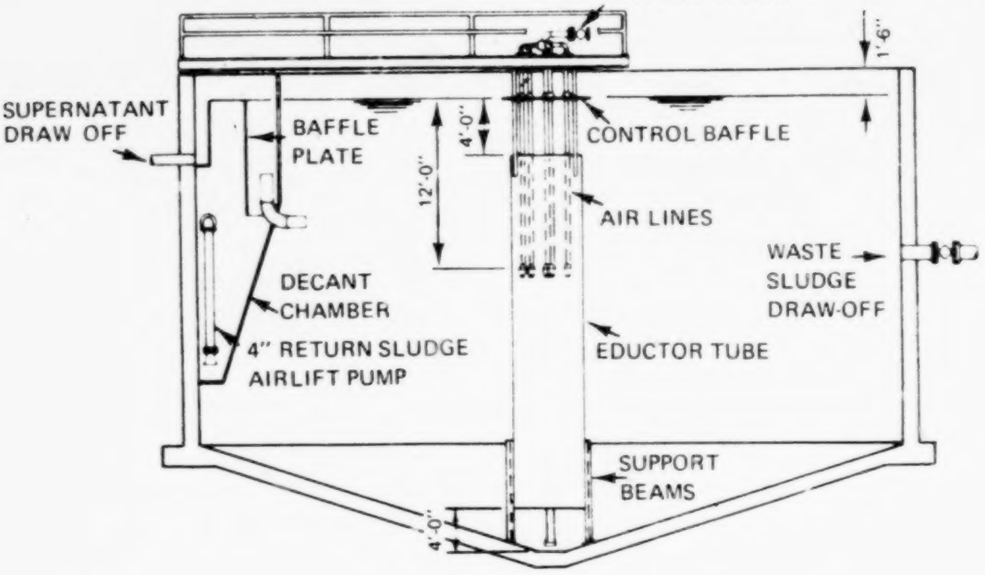
1. Determine solids volume to be dewatered
2. Determine capacity of unit based on past experience if available
3. Evaluate capture vs centrate quality

B. Problem Identification and Correction

1. Poor capture, cake density good
    a. Check pool depth if applicable and raise
    b. Lower feed rate if possible
    c. Add more polymer or evaluate other polymers for better capture
2. Cake density low, capture satisfactory
    a. Check pool depth, if high, lower until better density is obtained (if applicable)
    b. Vary dosage of ploymer
    c. Consider increasing bowl speed
3. Low cake density, poor capture
    a. Check feed rate, it may be too high
    b. Check polymer dosage, should clear up centrate
    c. Check pool depth, could be excessively high or low
4. Capture and cake density normal, but machine will not handle daily solids production
    a. Consider increasing flow to centrifuge and sacrifice centrate quality
    b. Check with manufacturer with regard to increasing bowl speed
    c. Increase aeration time
    d. Add chemicals
    e. Change speed ratio
    f. Check to see if characteristics of feed have changed


CLEAR OXIDIZED OVERFLOW TO PLANT
SETTLED SLUDGE RETURNED TO AERODIGESTER
PRIMARY SLUDGE
EXCESS ACTIVATED OR TRICKLING FILTER SLUDGE

AEROBIC DIGESTION SYSTEM
SCHEMATIC DIAGRAM


AIR PLUG VALVE
1'-6"
SUPERNATANT DRAW OFF
BAFFLE PLATE
4'-0"
CONTROL BAFFLE
12'-0"
AIR LINES
WASTE SLUDGE DRAW-OFF
DECANT CHAMBER
4" RETURN SLUDGE AIRLIFT PUMP
EDUCTOR TUBE
SUPPORT BEAMS
4'-0"

CIRCULAR AEROBIC DIGESTER

TROUBLESHOOTING GUIDE – SOLIDS HANDLING

IV. AEROBIC DIGESTION

- A. Process Evaluation Measures
  - 1. Determine dissolved oxygen
  - 2. Determine solid concentration
  - 3. Determine rate of air supply
- B. Problem Identification and Correction
  - 1. Low dissolved oxygen
    - a. Possible causes –
      - 1. Insufficient air supply
      - 2. Sludge overload
    - b. Corrections
      - 1. Increase air supply, if diffused air
      - 2. Increase submergence, if mechanical
      - 3. If maximum air is being introduced, lower solids content by drawing solids off to dry beds or other methods of disposal
      - 4. System may have received an unusual heavy loading, check O_2 uptake. Observe for several days. Oxygen uptake should subside, and D.O. should increase. If not, waste solids.
      - 5. Check on system – diffuser plugged
      - 6. Blocking of mechanical aeration
  - 2. Excessive Detergent Foam
    - a. Characterized by white to light brown light billowy foam. May look like soapsuds
    - b. Probable causes
      - 1. Low solids in the system
      - 2. ABS (non-biodegradable) detergents
    - c. Corrections
      - 1. Increase solids to approximately 1.5% or more by decanting and recycling solids back to system
      - 2. If solids concentration is sufficient, foam may be caused by non-biodegradable detergents (i.e. ABS) discharged by industry, usually textile. Correct by eliminating discharge, could use foam sprays in conjunction with a silicon based foam depressant for temporary relief
  - 3. Excessive Protoplasmic Foam
    - a. Characterized by a thick gelatenous foam that may cover entire reactor
    - b. Caused by excessive cell lysing usually associated with extremely high dissolved oxygen concentration, and high solids
    - c. Correction: lower oxygen input and/or solids in the system
    - d. Note: Protoplasmic Foam may not necessarily be a problem if contained within the reactor and desired results are obtained. Many aerobic digesters operate this way

V. SLUGE DRYING BEDS

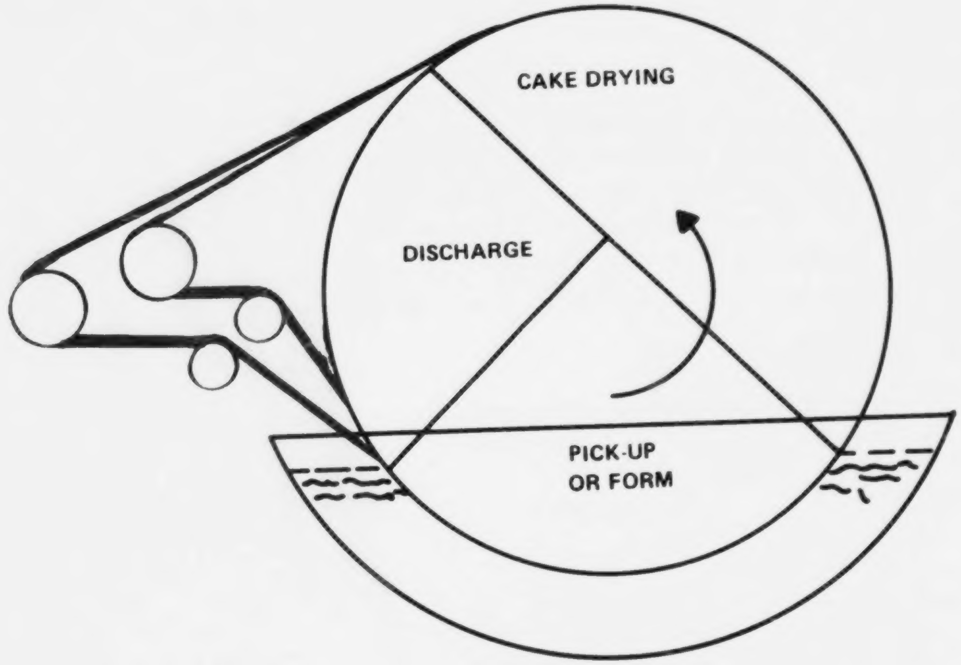
A. Process Evaluation Measures

1. Check sludge production against area available
2. Check records to determine actual application
3. Check records for actual drying time
4. Check records for sand replacement

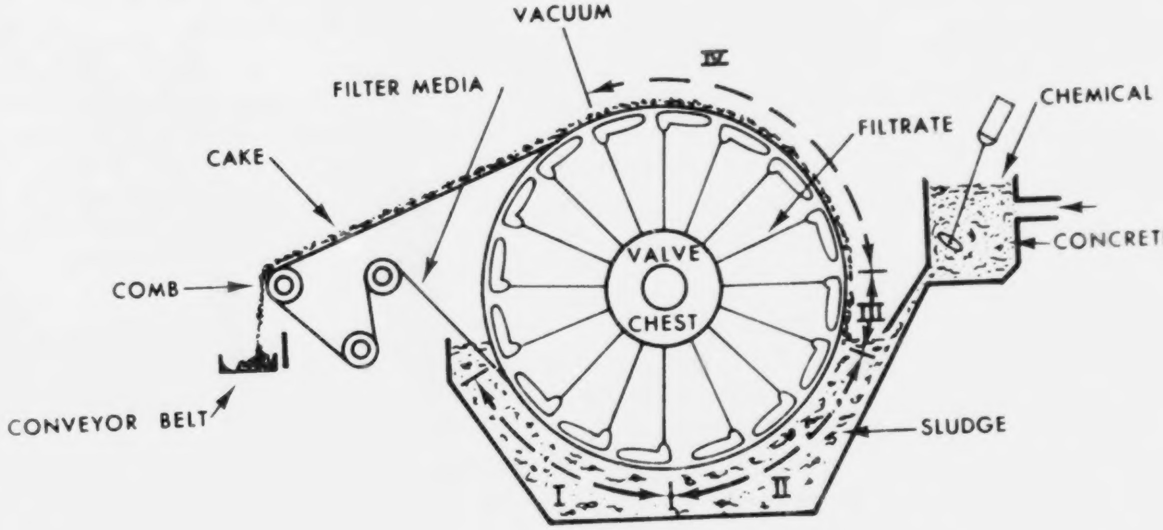
B. Problem Identification and Correction - the most common problem is excessive dewatering time

1. Possible Causes:
    - a. Excessive application of sludge on bed
    - b. Application of sludge on uncleaned bed
    - c. Dirty sand on bed surface
    - d. Plugged under drain system
    - e. Weather conditions
    - f. Septic sludge
    - g. Wrong chemical dose
2. Corrective measures
    - a. Excessive Application of Sludge on Bed
        1. When bed does dry, clean and prepare properly. Then apply a smaller amount (depth) on bed and evaluate. After sand media blinds the rest of the water is removed by evaporation. A good rule of thumb is to apply a load of sludge and measure the drawn down for the first three days. Twice the draw down should be the next application.
    - b. Application of Sludge on an Uncleaned Bed
        1. Little or no percolation will be observed. No corrective measures other than recognizing the problem and not doing it again.
    - c. Dirty Sand on Bed Surface

      No corrective measures advised after sludge has been drawn. After sludge has dried remove sludge and dirty sand. Replace with 1-2 mm clean sand.
    - d. Plugged Under Drain System
        1. With beds empty tie into underdrain piping with clean water and backflush into beds. Note: Always start water into beds *slowly*. Repeat this process until beds drain rapidly with the clear water. Broken pipes are a real possibility.
        2. A plugged underdrain system means that somehow sludge was allowed to enter the drain system. The media above the drain should be evaluated and replaced.


CAKE DRYING
DISCHARGE
PICK-UP
OR FORM

OPERATING ZONES OF A VACUUM FILTER


VACUUM
IV
FILTER MEDIA
CHEMICAL
FILTRATE
CAKE
CONCRETE
VALVE
CHEST
COMB
III
CONVEYOR BELT
SLUDGE
I
II

ROTARY VACUUM FILTER – CAKE PROCESSING

e. Insufficient Capacity to Handle Sludge Production
   1. Evaluate use of polymer. Normally high molecular weight cationic polymer works best. Normal dosage 5-30 lbs per ton of dry solids depending on molecular weight and charge.
   2. Ferric sulfate is often useful as a coagulant aid without damaging the usefulness of the sludge as a fertilizer. In many areas it can be purchased as spent pickel liquor. Ferric chloride may be used.

VI. VACUUM FILTRATION

A. Process Evaluation Measures
   1. Determine solids loading
   2. Determine cake concentration
   3. Determine filtrate concentration
      a. Should be less than 1.0%
   4. Determine chemical dosages
   5. Check dewaterability at dosage being used
   6. Check filter cloth condition
      a. Should be clean and not blinded

B. Problem Identification and Correction
   1. Thin poorly dewatered cake
      a. Possible causes
         1. Blind cloth
         2. Improper chemical dosage
         3. Low vacuum
         4. Improper cloth
         5. Speed too fast
         6. Submergence
      b. Corrective measures
         1. Blind cloth
            a. If dirty, steam clean and scrub with hot detergent
         2. Improper chemicals
            a. Determine proper dosage for good dewatering, then apply these dosages to the actual filter. Make field adjustments to achieve optimum results.
         3. Low vacuum in system
            a. Check all lines and relief valves for leaks, check drum operation and seals
            b. Repair where necessary or overhaul the vacuum pump

        4. Improper cloth (media)
            a. Check by running leaf test kit with best dewatered sludge. Run with different types of media until best one is observed. Change on actual filter if necessary.

2. Thick Poorly Dewatered Cake
    a. Possible causes
        1. High drum speed
        2. Low vacuum
        3. Too high a feed rate
    b. Corrective measures
        1. High drum speed
            a. Slow drum speed and observe difference in cake dryness. Sometimes filters have the ability to remove solids at a higher design rate, but this usually results in high moisture content.
        2. Low vacuum pressure
            a. This is usually associated with low yield, although the filter cake is thick. Normally the drum speed slowed down to compensate for the low vacuum.
            b. If vacuum is low, check piping, relief valves (if any) and seats in the filter system. Repair where necessary.
        3. Excessive feed rate
            a. Check solids yield on filter cloth.
            b. If excessive, reduce feed rate and chemical dosage rate accordingly.

REFERENCES – SOLIDS HANDLING

Process Design Manual, Sludge Treatment and Disposal. U.S. Environmental Protection Agency, Technology Transfer, October, 1974.

URS Research Company, Procedural Manual, Evaluating the Performance of Wastewater Treatment Plants. U.S. Environmental Protection Agency.

Zickefoose, C., and R. Hayes. Operations Manual, Anaerobic Sludge Digestion. Stevens, Thompson & Runyan. U.S. Environmental Protection Agency, February, 1976.

Gould, Robert F., ed., Anaerobic Biological Treatment Processes. A.C.S. Advances in Chemistry Series, 1971.

McCarty, Perry L., Anaerobic Waste Treatment Fundamentals. Public Works Magazine, Series of four articles, Sept. thru Dec., 1964.

LESSON – LAND TREATMENT

Instructor Overview of Lesson

Entry Level Behavior: Students will have had University training in Sanitary Engineering, waste treatment and/or related sciences or equivalent in experience and training. Some field experience in inspecting treatment plants, but none in operating waste treatment facilities.

As a prerequisite to this course, it is recommended that the student will be able to –

1. Identify treatment plant process units.
2. Describe treatment plant process units and equipment in technical terms.
3. Identify and explain the purpose of components of treatment plant process units, how they work and why they are important to the overall process.
4. Describe the normal operating procedures for treatment plant process unit components.
5. Identify when treatment plant process units are not operating properly.

Instructor Objectives: The principal instructor objectives for this lesson are:

1. To present the fundamentals of land treatment of waste effluents and sludge.
2. To discuss those aspects of land treatment which lead to good performance and those that lead to operational problems.
3. To provide a look at land treatment operational problems and to stimulate discussion on the causes of such problems.

References: Note list of references included with Student Notebook materials.

Total Length of Lesson: 3 subdivisions, 2 hours.

LESSON – LAND TREATMENT

Presentation Options for Course Director

The lesson on LAND TREATMENT is included for those areas of the country where land treatment of wastewater effluents, and land disposal of sludge are common. In areas where these practices are not common, this lesson probably should be excluded from the course.

The two-hour time period for this lesson is adequate compared to a total course length of 28 to 40 hours. If desired, the lesson could be shortened by reducing the presentation time for Subdivision 1, and even by eliminating subdivisions 2 and 3 if the Course Director is seeking to present only a brief overview of the subject.

If, for any reason, it is desired to lengthen this lesson, it would probably be desirable for the Course Director to obtain additional material geared specifically to the location where the course is being presented.

Some of the specific presentation options are as follows:

Subdivision 1 – Land Treatment Systems:

This subdivision is 1 hour, 15 minutes, and presents the basic elements of land treatment systems for wastewater renovation and for sludge disposal. This subdivision may be easily shortened or lengthened by deleting some of the existing content or by adding additional material, depending on the degree of emphasis the Course Director wishes to place on this lesson.

Subdivisions 2 & 3 – Troubleshooting Operational Problems, and Problem Analysis:

These two subdivisions go together. In subdivision 2 the students work in groups to identify the causes of operational problems, and in subdivision 3, these problems are discussed by the class. If the Course Director desires to retain a troubleshooting orientation for this lesson, then these two subdivisions should be presented as is.

LESSON OVERVIEW

Subtitle Title & Time	Major Student Objectives	Key Points & Content	Approach	Approach
1. Land Treatment Systems. 1 Hour, 15 Min.	1. Identify elements of land treatment systems. 2. Describe prior treatment requirements. 3. List the factors in transporting effluents and sludges. 4. Identify distribution systems. 5. Describe soil, crop, and outflow considerations in land treatment.	1. Similarity of effluent and sludge application. 2. Need for effective prior treatment. 3. Importance of uniform distribution. 4. Monitoring of sludge prior to application. 5. Need for monitoring outflow.	1. Instructor to follow lesson outline. 2. Use of word and picture slides, and key. 3. Stimulate student discussion. 4. Importance of student questions.	1. Slide series, 10 word slides and 26 picture slides and key. 2. Student Notebook page LT-1, Application Rate of Wastewater. 3. Student Notebook page LT-2, Wastewater Renovation Systems.
2. Troubleshooting Operational Problems. 25 Minutes	1. Recognize commong land treatment problems. 2. Determine alternative causes of problems.	1. Four operational problems for student groups to identify causes.	1. Students work in groups. 2. Instructor presents problem with a brief description and slides. 3. Group has 5 Minutes to identify the causes to each problem.	1. Slides to portray land treatment problems.
3. Problem Analysis. 20 Minutes	1. Evaluate responses to land application problems. 2. Identify specific causes to land treatment problems.	1. Causes of the following problems: a. Poolint of water b. Poor corn growth c. Broken pipes d. Soil Erosion	1. Students present their answers to problems presented in Subdivision 2. 2. Instructor stimulates class discussion.	1. Slides used in Subdivision 2. 2. Troubleshooting guide on land treatment problems Student Notebook pages LT-3 thru LT-9.

LAND TREATMENT

Lesson Plan – Subdivision 1 **Time: 1 hour, 15 Minutes**

Title: Land Treatment Systems

Instructor Objectives: To present the fundamentals of land treatment systems for sludge and wastewater effluents. To discuss those aspects of land treatment design and operation which either lead to good performance or to operational problems.

Student Objectives: As a result of this lesson subdivision, students will be able to do the following:

1. Identify and describe the four major elements of land treatment systems.
2. Describe the degree of treatment of wastewater effluents needed prior to land application.
3. List the constituents of sludge that may cause problems with land disposal.
4. List the important factors in the transportation of wastewater effluents and sludge for land application.
5. Identify the types of wastewater distribution systems and the advantages and disadvantages of each.
6. List the points for consideration in the application of sludge to land areas.
7. Describe key soil and crop considerations for land disposal of sludge.
8. Identify the three most important factors in establishing land application sites for wastewater effluents.
9. Recognize the importance of monitoring surface and subsurface runoff quality.

Training Materials:

Series of 10 word slides, and slide key

Series of 26 picture slides, and slide key

Student Notebook page LT-1, Application Rates of Wastewater Effluents to land areas, and page LT-2, Wastewater Cycle.

Classroom Set-up:

A normal classroom set-up will be required.

Students should be seated with their student groups.

35 mm carousel slide projector with remote controls

Large screen (8 ft x 10 ft)

Chalkboard or easel

Pointer

Subdivision Schedule:

Within the 75 minute time period, the following schedule should be observed in presenting the lesson plan outline:

TIME	SUBJECT
0 – 5 Minutes	Introduction to Land Treatment
5 – 15 Minutes	Prior Treatment
15 – 25 Minutes	Transportation of Sludge and Effluent
25 – 45 Minutes	Distribution of Sludge and Effluent
45 – 70 Minutes	The Land Area
70 – 75 Minutes	Summary and Questions

Subdivision Approach:

The instructor is to rely upon the lesson outline, and upon the word and picture slides and slide key. Student input and discussion is to encouraged and stimulated by the instructor. Because much of this material may be new to many of the students, their questions should constitute an important part of the lesson.

LESSON OUTLINE

I. Introduction to Land Treatment (5 Minutes)

A. Uses of Land Treatment

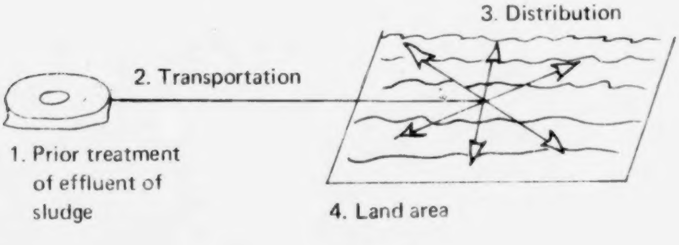
1. Widely used for disposal of sludge, primarily from small treatment plants in agricultural areas.
2. In several areas of the country, it is used for treatment of waste effluents.
3. Crop production and land reclamation may be very important secondary purposes of land treatment – however, the primary purposes are effluent treatment and sludge disposal.

B. Troubleshooting Land Treatment

1. Many operating principles are the same for land treatment of effluents and sludge.
2. Many problems are similar; therefore, troubleshooting approaches are similar.
3. This lesson is applicable to both effluent and sludge treatment, although most of the material was originally prepared to pertain to effluents.

C. Land Treatment Systems

1. Effluent Treatment systems and sludge disposal systems have four common elements.
   - a. Prior treatment at a treatment plant
   - b. Transportation to a site
   - c. Distribution over a land area
   - d. The land area itself
2. "LAND TREATMENT SYSTEM ELEMENTS"



KEY POINTS & INSTRUCTOR GUIDE

Key Points:
Similarity of effluent and sludge treatment systems.

Illustrate with the following slide
SLIDE LT-1 (Word)

LESSON OUTLINE

3. Each of these elements can create problems in the effectiveness of land treatment, and thus must be looked at in order to troubleshoot land treatment systems.
4. This lesson will look at each of these elements in detail – first from an operations point of view and then from a troubleshooting perspective.

II. Prior Treatment of Waste Effluents and Sludge (10 Minutes)

- A. Purpose of Land Treatment as a part of an Overall Waste Treatment System.
  1. Conceivably, any effluent can be applied to land
  2. Untreated sewage causes odor nuisance, health hazards, therefore, not presently acceptable to apply to land areas
  3. Treatment of secondary effluent – removal by land treatment system provides excellent advanced waste treatment and removals
  4. Therefore, most systems in use, and in the future will be for the final polishing of secondary effluents.
- B. Secondary Treatment Prior to Land Application
  1. Oxidation ponds normally used because:
     - a. they are most economical for small systems
     - b. they provide winter storage – which is absolutely necessary for land treatment systems
     - c. land is usually available
     - d. they meet EPA secondary standards
  2. Disadvantages of oxidation ponds
     - a. Too much land needed for large systems – over 5,000 people
     - b. Cold climates limit BOD loadings
  3. Other secondary processes are needed for larger systems, including:
     - a. anaerobic cell and faculative ponds
     - b. mechanical aeration – more costly

KEY POINTS & INSTRUCTOR GUIDE

Key Point:
Effective treatment is necessary in order to make land treatment feasible under current standards.

LESSON OUTLINE

C. Effluent Storage

1. Normal Irrigation Season: 26-30 weeks per year, therefore storage is needed. Depends on climate
2. Fill and draw oxidation ponds excellent for storage
3. Many ponds have 3 cells with piping flexibility for series and parallel operation

D. Expected Quality of Secondary Treatment Effluent — Land Treatment Influent

"EXPECTED QUALITY — LAND TREATMENT INFLUENT"

pH	7.5-9.2	NH_3-N	0.7-5 mg/l
5 day BOD	2-30 mg/l	NO_3-N	0.1-2 mg/l
DO	7-11 mg/l	Organic N	5-15 mg/l
SS	5-100 mg/l	Total P	2-7 mg/l

E. Purpose of Land Application of Sludge

1. To dispose of sludge more efficiently and less costly than by other methods, in a manner not creating other environmental problems.
2. To use as a soil conditioner and fertilizer for the production of crops (The value of sludge as a fertilizer is questionable).
3. To use as part of a land reclamation effort

"LAND APPLICATION OF SLUDGE PURPOSES BY ORDER OF PRIORITY"

1. To dispose of sludge:
   efficiently
   less costly than other methods
   environmentally sound
2. Soil conditioner to raise crops
3. Land reclamation

F. Prior Treatment of Sludge

1. Sludge should be stabilized, need not be dewatered
2. Concerns about applying sludge to farm land

"CONCERNS ABOUT SLUDGE CONTENT IN APPLYING SLUDGE TO LAND"

KEY POINTS & INSTRUCTOR GUIDE

Key Point: Quality of land treatment influent must be monitored during operations, and should be analyzed as part of troubleshooting.

SLIDE LT-2 (word)
Guide: Use Slide LT-2 to illustrate

Key Point: It is very important that the purpose of land application of sludge is kept in the proper perspective.

Guide: Illustrate this point with the following slide.
SLIDE LT-3 (word)

Guide: Use the following slide in presenting this point
SLIDE LT-4 (word)

LESSON OUTLINE

- Industrial waste residues, primarily metals
- Metals, can also be present in domestic wastes
- Pathogenic organisms

3. Removing industrial wastes – must be done at the source – there is no way of removing metals from sludge at a treatment plant
4. Pathogens – undesirable due to possible exposure
   a. Can be destroyed by storage, pasteurization, lime application, chlorine, other chemicals
   b. Survival of pathogens depends on organism, temperature, moisture, soil, organic matter present
5. Metals content in sludges
   Typical concentrations: dry basis

zinc	1,500 – 10,000 mg/l
copper	700 – 6,000 mg/l
nickel	200 – 600 mg/l
cadmium	40 – 800 mg/l

III. Transportation of Sludge and Waste Effluents (10 Minutes)

A. Transportation of Sludge
   1. Cost factor usually determines method of transportation
   2. Methods – tank truck, barge, rail, pipeline
   3. For small communities with land available – trucks afford greatest flexibility
   4. Retention capacity at plant or site can make transportation flow more even – handle sludge when it is not being spread.

B. Troubleshooters will probably have the greatest opportunity to provide assistance to small communities, where sludge is transported by truck, as shown in the following slides:
   1. Trucks are more maneuverable than pipelines This one has a vacuum pump to get the sludge or scum into the tank, gravity to let it out.

KEY POINTS & INSTRUCTOR GUIDE

SLIDE LT-5 (picture)

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
2. The previous view showed a 1,600 gal unit, this one carries about 3 times that amount	SLIDE LT-6 (picture)
3. Another tank hauling unit. Note the spreader outlet and tire support. A low tire loading factor is advisable for field application	SLIDE LT-7 (picture)
4. One tank loading piping hookup is shown in this view. Protection from overfilling better be good to avoid a messy cleanup of poor public relations	SLIDE LT-8 (picture)
C. Transportation of Waste Effluents	
1. Land treatment areas are generally close to the secondary treatment plant, unlike some sludge disposal areas.	
2. Pipelines are generally used	
3. The key to transportation of waste effluents is adequate pumping, to maintain adequate flows and pressure in wastewater irrigation distribution systems.	
4. Canals may be used in some areas where flood irrigation methods are used.	
D. Importance of proper control over pumping system for waste effluents.	Key Point: Control over pumping system.
1. Proper flow is key to adequate distribution, which in turn is key to maximum renovation of wastewater.	
2. Pressure is key to flow.	
3. Improper flows and pressures can damage system as well as create distribution problems.	
"CONTROL OVER WASTE EFFLUENT PUMPING SYSTEMS" • Distribution is key to effective wastewater renovation • Flow is key to distribution • Pressure is key to flow • Improper flows damage system	Illustrate these points using: SLIDE LT-9 (word)
E. To provide control over pumping systems, the following means are used.	

LESSON OUTLINE

"CONTROL PUMPING SYSTEMS BY"

- Flow meters
- Automatic pressure recorders
- Inflow automatic sampler
- Pressure relief valve
- Automatic shutoff for high partial vacuum

1. Flow meters – measures rate of flow in gpm.
   a. Use from station to station, measure variations and balance in flows
   b. Flow rate too high – can break lateral or riser
   c. Flow rate too low – can clog nozzles
   d. Daily records of flow volumes represent a permanent record over entire irrigation system
2. Automatic Pressure Recorders
   a. Provides available, visual and continuous record throughout the system
   b. Pressure plus flow records – valuable for system evaluation and troubleshooting
   c. High and low pressure signaling attachments – provides continuous information necessary to assure uniform distribution
3. Automatic Sampler for Influent – Provides records of quality of wastewater inflow.
4. Pressure relief valve.
   a. Protects system if line valves do not open
   b. Handles flows as additional pumps come on line
   c. Protects against water hammer and air shock loads
5. High Partial Vacuum Automatic Shutoff
   a. Protects pumps against excessive partial vacuum at inlet
   b. High vacuum causes pump cavitation
   c. Condition can be caused by clogging of pump screen

KEY POINTS & INSTRUCTOR GUIDE

SLIDE LT-10 (word)

Guide: Leave this slide on while providing additional detail contained in lesson outline.

LESSON OUTLINE

IV. Distribution of Waste Effluents and Sludge (20 Minutes)

The wastewater distribution system is an important determinant in the quality of wastewater renovation at a treatment site, and on crop growth.

- A. General Factors of Wastewater Distribution
  - 1. Importance of uniformity of distribution.
    - a. There should be less than 10% variation across receiving area
    - b. Creates best renovation of wastewater and crop growth
  - 2. Most Systems – distribution pattern needs to be measured physically on the actual land area.
  - 3. There are three principal types of distribution.
    - a. Flood irrigation
    - b. Spray irrigation
    - c. Ridge & furrow application – restricted to southwest U.S. due to soil, climatic and vegetative conditions
- B. Flood Irrigation
  - 1. Advantages
    - a. No wind drift, therefore, little border or buffer area is needed
    - b. Some states do not require chlorination
    - c. Some areas can be flooded by gravity, therefore, no pumping and electrical costs
  - 2. Disadvantages
    - a. Obtaining uniformity of distribution
    - b. Difficulty of automating
    - c. Difficult to maintain proper field grades

"FLOOD IRRIGATION"

Advantages	Disadvantages
– No wind drift	– Flow uniformity
– No chlorination some states	– Difficult to automate
– Flood by gravity – low cost	– Difficult to maintain grades

KEY POINTS & INSTRUCTOR GUIDE

Key Point: Uniformity of distribution.

Guide: Illustrate this section with the following slides.

SLIDE LT-11 (word)

LESSON OUTLINE

C. Spray Irrigation
  1. Most common form of land application of waste effluents
  2. Importance of system pressure – with uniform sprinkler size, flow rate is a function of pressure
     a. Therefore, to control or troubleshoot system, monitor pressure
     b. 20% pressure difference causes a 10% flow difference
     c. Pressure gauges with Pitot tube adaptors provide rapid field evaluation of the distribution system
  3. Portable Aluminum Spray Irrigation Systems
     a. Usually used as auxiliary equipment for special areas
     b. Used for small areas
  4. Traveler Systems
     a. Low initial cost, flexibility of areas that can be irrigated
     b. Can distribute wastewater with large solids particles
     c. Disadvantages: take much labor
        difficult to automate
        produce much wind drift
  5. Center Pivots
     a. Relatively low operating cost
     b. Low capital cost compared to solid set systems
     c. Difficult to operate in very wet and muddy conditions
     d. Appreciable amount of exposed equipment
     e. Requires circular farming pattern – or cannot irrigate entire rectangular field
  6. Solid Set Spray Irrigation System
     a. Can be rigged to accommodate shape of field
     b. Can be set up more quickly than center pivot rig – for any time of year

KEY POINTS & INSTRUCTOR GUIDE

Key Point: The importance of proper pressure in a spray irrigation system.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
D. Slides on Wastewater Distribution	Guide: The following slides show different wastewater distribution systems.
1. Portable pipe can be used for small systems but frequently require much labor and cause management and operational problems	SLIDE LT-12
2. This buried, solid-set system saves the labor and reduces the management problems	SLIDE LT-13
3. Especially when the valves are automatically changed by a controller	SLIDE LT-14
4. Center pivot systems can cover up to 200 acres in one circle	SLIDE LT-15
5. Self-propelled travelers have the advantage of economy and the ability to distribute liquids with large solids	SLIDE LT-16
6. Self-propelled, however, means different things to different people. Some people did not like the idea of us using these on *airport* grass runways	SLIDE LT-17
7. In reality, they follow a very well-defined path and can be used many places center pivots cannot . . .between roads and beside trees	SLIDE LT-18
8. When debris content is great and particle size is large remove the screens and use a large nozzle. Or use a self-cleaning screen back at the pumphouse.	SLIDE LT-19
9. For proper soils, flood irrigation has its place . . .	SLIDE LT-20
10. Also, so does irrigating with siphons, BUT usually not for irrigating wastewater year-around	SLIDE LT-21 Guide: Use the following word slide to discuss the importance of application rates.
E. "APPLICATION RATE AN IMPORTANT VARIABLE FOR" • Renovation of wastewater • Removal of effluent constituents • Crop success • Drainage • Erosion	SLIDE LT-22 (word) Guide: Note to students that detailed information on application rates is presented in Student Notebook p LT-1.

LESSON OUTLINE | **KEY POINTS & INSTRUCTOR GUIDE**

F. Drainage
  1. Drainage is a critical aspect of System management
  2. Preferred procedure — install good surface drainage on irrigated area, which will
     a. Dispose of snow melt, interflow, natural precipitation
     b. Keep maximum soil — water capacity for renovating wastewater
  3. Drainage depends on site, soil, and groundwater conditions
     a. Some can be drained economically
     b. Some areas, high clay content, can't install reasonable tile drainage system

G. Application of Sludge
  1. Ridge and furrow method — level land and cold climates
  2. Spray irrigation — more flexible, need less soil preparation
  3. Rates — can vary from 0.5 to 100 tons per acre
  4. To support crop nitrogen needs — usually 5 to 10 tons per acre of liquid digested sludge
  5. Points for consideration or monitoring during sludge application
     a. Trace element composition of sludge application
     b. Nitrogen content of sludge, soil, and crops, and potential for nitrate pollution to groundwater
     c. Use of only disinfected sludge on low growing fruits and vegetables
     d. Hydraulic overloading of soil
     e. Ultimate use of the land
     f. Runoff and erosion control practices

Key Point: Sludge must be monitored during application to the land.

  6. Slides on sludge application
     a. This view shows a simple outlet device for the previously shown tanker. The extra flexible tubes are for hookup to onsite storage such as for piped sludge applicators.

SLIDE LT-23

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

b. Another sludge spreader device. The sludge must have floated in the tank as this is mostly water. If anaerobic sludge isn't degassed, it tends to float. The sludge will appear later. There are at least as many options for sludge spreading as for trickling filter nozzles. As long as they are workable, they may be used.

SLIDE LT-24

c. Spreading sludge on a cover crop area or forest land has to be limited to acceptable rates. A high application rate needs to be worked in to avoid odor nuisances. It also provides better soil conditioning.

SLIDE LT-25

V. The Land Area – For Sludge Disposal and Wastewater Renovation. (25 Minutes)

A. Soil Considerations for Sludge Disposal

1. Soil properties to consider for sludge assimilation
   - a. Depth
   - b. High infiltration and percolation capacity
   - c. Fine texture for water and nutrient holding capacity
   - d. Good drainability and aeration
   - e. Neutral or alkaline pH

2. Fertilizer properties
   - a. Half of nitrogen and potassium is in liquid phase, therefore, is lost upon drying or dewatering
   - b. Potassium to N or P ratio is low, therefore, there is not enough potassium if sludge application rate is designed to serve nitrogen needs
   - c. Primary nutrient content – liquid digested sludge, 25% of dry weight
     Nitrogen 3.5 – 6.4%
     Phosphate 1.8 – 8.7%
     Potash 0.24 – 0.84%

Key Point: Nutrient properties of sludge are critical both to crop growth and over fertilization.

LESSON OUTLINE

3. Nitrogen is generally the limiting factor on appliction
    a. Excess nitrogen pollutes groundwater with nitrates
    b. High nitrogen content toxic to humans and animals
    c. Can create excessive nitrates in crops
    d. There is no "cookbook" determination as to the proper rate of sludge application to limit nitrates; soil type, geology, climate, crops and farm management are all factors that determine rate
4. "FERTILIZER PROPERTIES OF SLUDGE"
    Liquid digested sludge
    - Nitrogen: 3.5 – 6.4%
    - Phosphate: 1.8 – 8.7%
    - Potash: 0.24 – 0.84%

    Limiting factor – nitrogen

    Excess nitrogen – pollutes groundwater, damages crops, toxic to animals

B. Crop considerations
    1. Crops vary widely in reaction to sludge enriched soils
    2. May be affected by trace elements, and could concentrate such elements to inhibit future use
    3. Reaction of crops is generally site dependent

C. Land Reclamation – Sludge can be used to reclaim strip mines and other disturbed land surfaces
    1. High application rates commonly used can lead to water contamination without proper drainage controls
    2. Leachates may be treated before being discharged, as can surface runoff
    3. Accumulation of sludge can lead to accumulation of trace elements
    4. Neutral pH minimizes toxicity

KEY POINTS & INSTRUCTOR GUIDE

Illustrate nutrient properties with the following slide.
SLIDE LT-26 (word)

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
D. Slides on Land Areas for Sludge Disposal	
1. This chart of corn yield versus sludge application rate is self-explanatory. Sludge is a low grade fertilizer; it contributes water, organic conditions, base exchange capacity, trace nutrients and more favorable soil structure. Certain excess metals and other damaging pollutants may be a problem unless controlled at the source.	SLIDE LT-27
2. This coal mine acid drainage area may be reconditioned by grading and sludge application.	SLIDE LT-28
3. This view of a graded mine spoil area was covered with 3 inches of sludge three years prior to this late summer view. The area to the right reseeded and supported good growth. The barren area to the left wasn't covered with sludge. Seeds falling on this area turned brown after contact with the highly acid soil.	SLIDE LT-29
4. The lush green of this field is the result of sludge treatment a year earlier. One crop of hay has been removed, another is on the way. The dark colored area in the background on either side of the green strip is sludge application area. As one Englishman phrased it – this means meat, bread and beer – a combination that is difficult to surpass.	SLIDE LT-30
E. Renovation of Wastewater on Land Areas	
1. Above all, it must be remembered that the purpose of wastewater renovation is to obtain a high quality effluent.	
2. Site factors – There are three important site factors that need to be considered in establishing and operating wastewater renovation systems.	Guide: Illustrate by using the following slide
"KEY SITE FACTORS FOR WASTEWATER RENOVATION" • Soils – determine design and type of system • Crops – Management of crops secondary to wastewater concerns	SLIDE LT-31 (word)

LESSON OUTLINE

- Outflow – Only indicator of renovation efficiency

F. Soils – Variation in soils necessitates different design and operations for land application of wastewater

1. Soil Characteristics
    a. Sandy soil, deep water table, where extensive renovation not required, use flooding/infiltration – percolation
    b. Tight clay soils – use overland, flow grass filtration
    c. Spray irrigation, if properly designed, applicable to full range of soil conditions
    d. Too much organic material in wastewater – can decrease infiltration and increase runoff
2. Erosion
    a. Easily eroded soils, and slopes, should be kept in grass cover
    b. Mild slopes – use steps of grass and corn
    c. Flat site – use corn crop year after year
    d. Small area field trials useful to determine preferred procedure for any location

G. Crops. Management of crops must be done in conjunction with the most appropriate wastewater treatment scheme, and not necessarily for maximum crop production

1. Quality of crops
    a. Often indicates good or poor trends
    b. Crop killed by excess water or constituents of wastewater can't properly function as a "living filter" for wastewater renovation
    c. Corn problems – for example:
        1. Dark green – removing much nitrogen
        2. Light yellow – insufficient nitrogen, or a drainage problem
        3. Small stalks – drainage problem – water table, insufficient root growing area
    d. Excesses of some elements prevent uptake in others

KEY POINTS & INSTRUCTOR GUIDE

Guide: These points are expanded upon in the following sections.

Key Point: Soil erosion can be a major problem that occurs with land application of wastewater

LESSON OUTLINE

2. Harvesting of crops
   - a. Should be harvested and removed from area
   - b. Best to remove entire crop, i.e. – corn for silage rather than just the ears
   - c. Trees – Less renovation, nutrients recycled with leaf fall
   - d. For nitrogen removal – leave organic matter on area as a carbon source
3. Farm and crop management
   - a. Sound agricultural skills needed
   - b. Assistance available from Soil Conservation Service – wastewater treatment plant troubleshooters can't be expected to be experts in agriculture

H. Outflow. Surface and subsurface quality are the only true indicators of renovation efficiency at a treatment site. Therefore, continual and permanent monitoring systems must be used, and relied upon to understand the effectiveness of treatment.

1. Spray irrigation systems
   - a. Designed so there is no direct runoff of wastewater
   - b. Snow melt and precipitation – should runoff freely
   - c. Interflow – should drain freely, and meet quality standards
   - d. All runoff locations – should be monitored and a permanent record kept
2. Overland flow systems
   - a. Designed for wastewater to run over soil, and away from site in surface channels
   - b. Removal of overland flow – suspended solids removed by grass filtration, 50% phosphorus removed by direct contact with soil and plants, nitrogen – by conversion to nitrogen gas
   - c. Local regulations and standards often determine type of irrigation system used.
3. Underground outflows
   - a. Must still be monitored
   - b. Use buried tiles to remove renovated

KEY POINTS & INSTRUCTOR GUIDE

Key Point: Need for monitoring of outflow.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
water at areas with well drained soils and high water tables.	
c. Deep wells or suction lysimeters used to monitor sites with deep water tables	
4. Removal rates for well-designed and managed spray irrigation systems	
a. Phosphorus 90-95%	
b. Nitrogen 70-90%	
c. Suspended Solids nearly all removed in top 4 ft of soil	
I. Slides on Wastewater Renovation Areas	
Monitoring systems should have been installed before irrigation was started. The monitoring data establish baseline conditions for system evaluation.	SLIDE LT-32
Suction lysimeters frequently are used for monitoring the degree of renovation. These lysimeters should be tested for leaks before being installed.	SLIDE LT-33
A suction lysimeter installed in a check plot for comparing data obtained within the irrigated plots.	SLIDE LT-34
The preferred procedure is to remove both stalk and ear for maximum removal of nutrients. That is, unless you need the stalk's organic matter as a carbon source.	SLIDE LT-35
A good grass cover reduces erosion. Also is a very good user of nitrogen (Reed Canarygrass).	SLIDE LT-36
In our evaluation and troubleshooting procedures, we are always striving for good quality crops and a pleasing environment . . . both very helpful in public relations and just being good neighbors, and a cost reducing element.	SLIDE LT-37
Example of good lagoon treatment and solid-set spray irrigation facility at Middleville, Michigan.	SLIDE LT-38
VI. Summary and Questions (5 Minutes)	
A. Briefly summarize key points in land treatment	Guide: Summarize by referring class to Student Notebook diagram, p. LT-2
1. The importance of prior treatment and sludge handling	
2. Transportation of sludge and waste effluents	
3. Distribution	
4. The land areas, and factors which must be considered	
B. Use remaining time for questions	

LAND TREATMENT

Lesson Plan – Subdivision 2 **Time: 25 Minutes**

Title: Troubleshooting Operational Problems

Instructor Objectives: To provide a look at operational problems that occur in the operation of land treatment systems for wastewater effluents.

Student Objectives: As a result of this lesson subdivision, students will be able to do the following:

1. Recognize some common operational problems in the application if wastewater effluents to land treatment areas.
2. Determine the likely alternative causes of operational problems for land treatment areas.

Training Materials:

Slides, used in sequence, to portray land treatment problems to the class.

Instructor's lesson plans contain slide key – problem guides for use in presenting problems to the class.

Classroom Set-up:

A normal classroom set-up will be required. Students *must* be seated with their student groups.

35 mm carousel slide projector with remote controls

Large screen (8 ft x 10 ft)

Chalkboard or easel

Pointer

Subdivision Schedule:

Within the 25 minute time period, the following schedule should be observed in presenting the lesson plan outline.

TIME	SUBJECT
0 – 5 Minutes	Introduce problem session to class
5 – 10 Minutes	Problem 1 – Pooling of water
10 – 15 Minutes	Problem 2 – Poor corn crop
15 – 20 Minutes	Problem 3 – Broken Pipe
20 – 25 Minutes	Problem 4 – Erosion problem

Subdivision Approach:

The instructor presents four (4) land treatment problems to the students, as follows:

1. Seat students in 4-person groups previously selected by the course director. Students need note paper to record their answers.

2. Each problem is allotted approximately 5 minutes, as follows:

   1 minute – presentation by instructor using slides

   4 minutes – analyses by student groups

3. For each problem, the instructor is to show the designated slides, according to the lesson plan outline, from which the students are to identify the possible causes of the problem

4. The instructor may answer questions as to the nature of the problem – or as to what each slide depicts

5. Student participation and discussion within each group should be encouraged

6. After 5 minutes, the instructor must go to the next problem

7. Following the subdivision, there will be a 20 minute subdivision for the class to discuss and analyze the problems presented

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
I. Introduction to Problem Analysis (5 Minutes)	
A. Make sure students are seated with their groups. They will be needing paper to record the answers to the problems being presented to them.	
B. Briefly review the instructions.	
C. Stress that you are looking for the students to apply the Process of Troubleshooting, by using a systematic approach to find possible alternative causes to the problems presented.	
D. Stress that student participation and involvement is sought.	
II. Problem 1 (5 Minutes)	
A. Problem Statement – read to class. You arrive at a land application site and observe the following situations:	Guide: 1 Minute
B. Show the slides depicting the problem. (Pooling of water, and sinkholes)	SLIDE LT-39 SLIDE LT-40
C. Ask the student groups to list the possible causes of the problem.	Guide: 4 Minutes.
III. A. Problem Statement – read to class At another site, the farmer who is farming the site for the town shows you an ear of corn from his farm (left hand) and from the spray irrigation area (right hand). He says he thinks that something's wrong.	Guide: 1 Minute
B. Show the slide depicting the problem.	SLIDE LT-41
C. Ask the student groups to list the possiblecauses of the problems.	Guide: 4 Minutes.
IV. Problem 3 (5 Minutes)	
A. Problem Statement – read to class. Several of the installations you visit seem to be having problems with the piping used to transport wastewater effluents. You have seen examples like this:	Guide: 1 Minute

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
B. Show the slides depicting the problem.	SLIDE LT-42 SLIDE LT-43 SLIDE LT-44
C. Ask the students to list the possible causes of the problem.	Guide: Repeat the slides once or twice during this problem.
V. Problem 4 (5 Minutes)	
A. Problem Statement – read to class	Guide: 1 Minute.
The operator of a wastewater renovation site indicates that his monitoring records show that ourflow quality has deteriorated. You inspect the site and find what's shown on the slide. (Soil erosion by way of a large rut)	
B. Show the slide depicting the problem	SLIDE LT-45
C. Ask the students to list the possible causes of the problem.	

LAND TREATMENT

Land Plan – Subdivision 3 **Time: 20 Minutes**

Title: Problem Analyses

Instructor Objectives: To stimulate discussion on the causes of operational problems on the land application of wastewater effluents. To provide students with specific answers to the four problems presented in subdivision 2.

Student Objectives: As a result of this lesson subdivision, students will be able to do the following:

1. Evaluate their responses to land application problems in relation to the causes of the problems provided by the instructors.
2. Identify specific causes to land treatment problems.

Training Materials:

Slides presented in subdivision 2 are to be re-shown during subdivision 3.

Classroom Set-up:

A normal classroom set-up will be required. Students *must* be seated with their student groups.

35 mm carousel slide projector with remote controls

Large screen (8 ft x 10 ft)

Chalkboard or easel

Pointer

Subdivision Schedule:

Within the 20 Minute time period, the following schedule should be observed in presenting the lesson plan outline.

TIME	ACTIVITY
0 – 5 Minutes	Reporting and discussion of Problem 1
5 – 10 Minutes	Reporting and discussion of Problem 2
10 – 15 Minutes	Reporting and discussion of Problem 3
15 – 20 Minutes	Reporting and discussion of Problem 4

Subdivision Approach:

1. Students should remain in the student groups used in subdivision 2.
2. Instructor should call on one group to give their input on the likely causes of each of the four problems shown in subdivision 2.

3. After each presentation, ask the other groups if they have any additions, or changes.

4. If a problem is not fully analyzed by the class, use materials provided in the lesson plan outline to supplement the discussion.

5. The instructor should serve as a discussion catalyst for this subdivision. He should minimize his own role and maximize student participation.

6. After 5 minutes, move on to the next problem.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
I. Guide to Problem 1 (5 Minutes) A. Identity of Problem The slides show farmed areas that contained pooled water areas and sinkholes	Reshow slides: LT-39 LT-40
B. Possible Causes 1. Broken pipe 2. Inoperative valve or other malfunction in the pipeline system 3. Improper choice of site – poor soils for irrigation 4. Irrigation at a rate beyond the capacity of the land area	Guide: Call for class discussion of possible causes.
II. Guide to Problem 2 (5 Minutes) A. Identity of Problem The slide shows a small corn ear, cobs not filled out with kernels, yellow corn leaves, and the crop generally not responding	SLIDE LT-41
B. Possible Causes 1. Too much water applied – over irrigation 2. Too little nutrients applied 3. Nutrients applied too early, perhaps wrong type of nutrient	Guide: Call for class discussion of possible causes.
III. Guide to Problem 3 (5 Minutes) A. Identity of Problem The slide shows deterioration of lateral distribution pipe	
B. Possible Causes	Guide: Call for class discussion.
1. Effluent permitted to remain in aluminum pipe too long. Thus, nutrients in wastewater and dissimilar metals produced electrochemical corrosion. This would be expected between steel valves and spring and aluminum pipe.	SLIDE LT-42
2. This happens also at grain boundaries along the pipe – after a certain amount of deterioration a pressure surge splits the pipe.	SLIDE LT-43

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
3. Plastic pipe does not solve the problem of above ground surface lines . . .since during very cold weather, plastic pipes are easily broken due to shockloads. In direct sunlight, plastic pipe deteriorates and then ruptures due to pressure surges. The high expansion also causes problems with riser locations and with leaks in very cold weather.	SLIDE LT-44
IV. Guide to Problem 4 (5 Minutes)	
A. Identity of Problem The slide shows a rut caused by erosion of the farm area	SLIDE LT-45
B. Possible Causes 1. Excessive application rate of wastewater 2. Soil conditions not compatible with application rate 3. Crop cover not compatible	Guide: Call for class discussion.
V. Lesson Summary Note that the Student Notebook pages LT-3 thru LT-9 contain troubleshooting guides on how to deal with the following common operational problem.	
A. Problems in Pumps and Pumping 1. Low Pressure, high flow 2. High Pressure, low flow 3. Low pressure, low flow	
B. Problems in Wastewater Distribution Systems 1. Deterioration of lateral distribution pipe 2. No flow from certain sprinkler nozzles 3. Adequate management and operation of distribution systems 4. Spray from wind drift	
C. Land Renovation Areas 1. High overland runoff 2. Soil erosion 3. Dead crops 4. Water pooling, sinkholes 5. Poor crops	

STUDENT NOTEBOOK MATERIALS

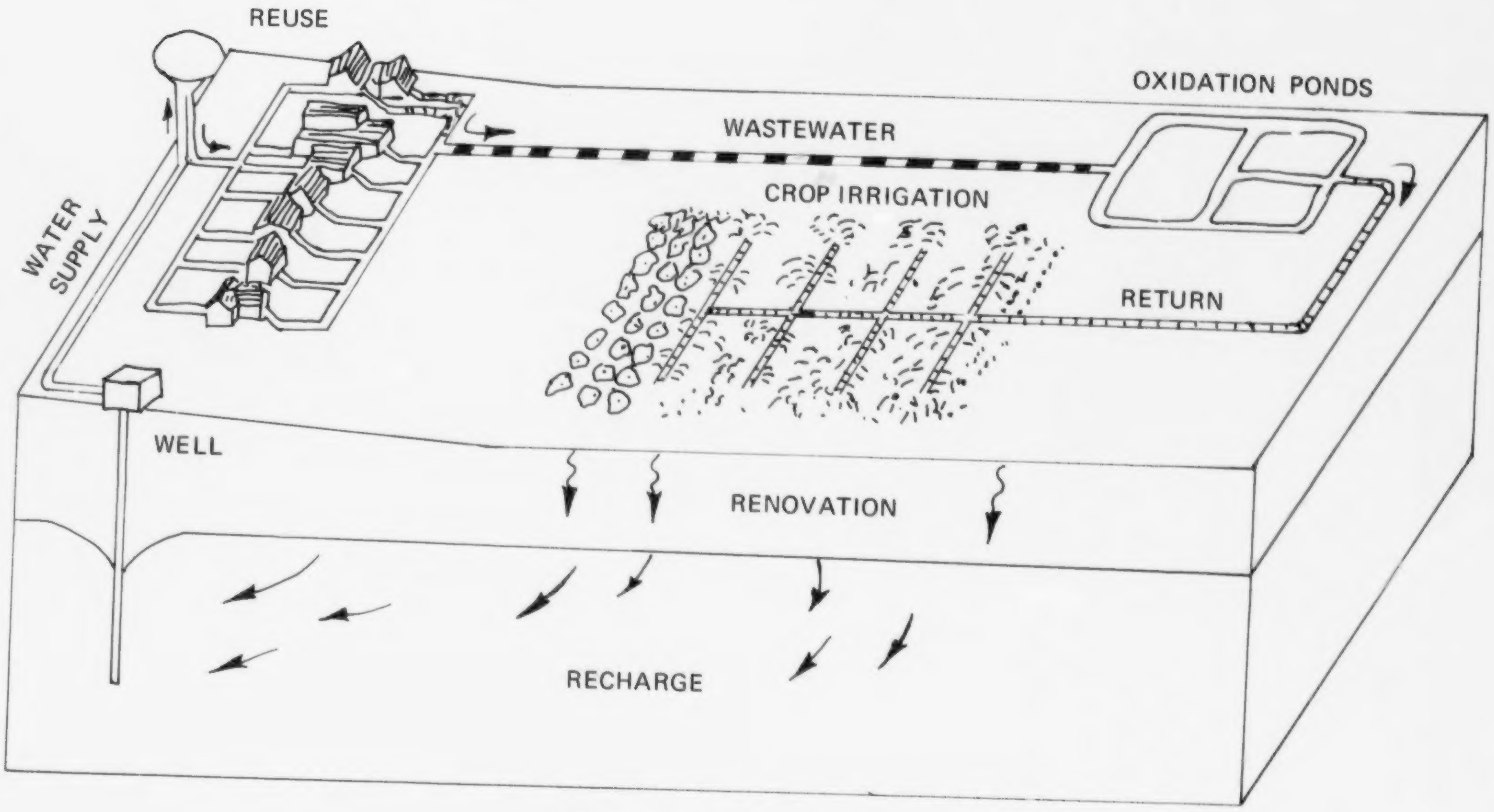
The following materials are included in Section 12 of the Student Notebook, Land Treatment. The Notebook is distributed to students at the start of the course, and is available to them as a reference material throughout the course. Some of these materials are to be used by the instructor as an integral part of the lesson.

Index of Notebook Materials

Pages	Material	Use in Lesson
LT – 1	Application Rates of Wastewater Effluents to Land Area	Reference by Instructor, Subdivision 1
LT – 2	4-R Cycle of Wastewater Renovation and Conservation	Reference by Instructor, Subdivision 1
LT – 3 thru LT-9	Troubleshooting Guide – Land Treatment	Reference by Instructor Subdivision 3
LT – 10	References	

APPLICATION RATES OF WASTEWATER EFFLUENTS TO LAND AREAS

1. Hydraulic Loadings
   - a. Depends on infiltration capacity and conductivity of underlying geological materials
   - b. 1.5 to 4.5 inches per week, 26 to 30 weeks per year, normal rate
   - c. Well drained sandy soils — can use over 3 inches per week
   - d. Design loading rates can't exceed vertical percolation rate, and shouldn't create excessive buildup of groundwater
2. Organic loading
   - a. Depends on soils, depth of groundwater, crop, type of system
   - b. Spray irrigation, normal loads of 100 to 500 pounds per acre per year
   - c. Seepage basins — normal loads of 400 to 1,600 lb/acre/year
3. Nitrogen loading
   - a. Varies by nitrogen concentration and hydraulic loading rate
   - b. Penn State — 355 lb/acre/year yielded 97.3% removal
   - c. Normal variation, spray irrigation, 50 to 250 lb/acre/year
   - d. Seepage basins, normal variation, 150 to 650 lb/acre/year
4. Phosphorous Loading
   - a. Penn State — 99.2% removal at 133 lb/acre/year
   - b. Spray Irrigation, normal rate, 40 to 125 lb/acre/year
   - c. Seepage basins, normal rate, 100 to 400 lb/acre/year


REUSE
OXIDATION PONDS
WASTEWATER
CROP IRRIGATION
WATER SUPPLY
RETURN
WELL
RENOVATION
RECHARGE

4-R CYCLE OF WASTEWATER
RENOVATION AND CONSERVATION

TROUBLESHOOTING GUIDE – LAND TREATMENT

I. Wastewater Pumping

  A. *Problem – Pressure for a particular setting is below normal; however, the flow is above normal.*

    1. Possible Causes

      a. Broken main, lateral, riser, or gasket
      b. Missing end plug, sprinkler, or nozzle tips
      c. Too many laterals on at same time

    2. Most serious effects

      a. Low pressure; therefore, poor distribution
      b. Poor distribution; therefore, poor renovation
      c. Increased flow may cause increased horsepower and motor overload
      d. High flow can cause pump cavitation

    3. Corrections

      a. Properly set automatic signaling device if pressure is below normal – AND when exceptionally low, automatic pump cutoff
      b. Normal Maintenance and Operation relative to the malfunctions listed

  B. *Problem – Flow for a particular setting is below normal; however, the pressure is above normal.*

    1. Possible causes

      a. Series of nozzle tips or sprinklers clogged
      b. Lateral risers or valves clogged or partially clogged
      c. Lateral screens may be clogged
      d. Lateral valve may not have opened
      e. Wastewater frozen anywhere in system

    2. Most serious effects

      a. High pressure can cause too much water in areas where sprinklers are operating
      b. Too much water at any one location causes renovation problems
      c. Too high pressure can cause wind drift and problems with the neighbors
      d. Too high pressure can rupture lines, causing all types of problems – pollution, with neighbors, hydraulic, etc

3. Correction
    a. Properly set automatically signaling device if pressure is above normal – AND when exceptionally high, automatic pump cutoff
    b. Normal maintenance and operation relative to the malfunction possibilities

C. *Problem – Both pressure and flow are below normal for all settings of the distribution system.*

1. Possible causes
    ~~a.~~ Too much sand and grit in wastewater and impeller blades are worn
    b. Too much wear in pump
    c. Partially clogged suction or inlet screen

2. Most serious effects
    a. Low pressure and poor distribution, renovation problems
    b. Inability to pump enough water to keep up with inflow
    c. Partially clogged screen on inlet to pump could cause cavitation and require financial outlay for entirely new pump

3. Corrections
    a. Regular and detailed evaluation and troubleshooting by one having expertise in these areas
    b. Use of properly installed and operating automatic pump cutoff for high partial vacuum on suction side of pump

II. Wastewater Distribution Systems

A. *Problem – Deterioration of lateral distribution pipe, at ends or throughout pipe.*

1. Possible causes
    a. Effluent permitted to remain in aluminum pipe too long. Thus, nutrients in wastewater and dissimilar metals produced electro-chemical corrosion. This would be expected between steel valves and springs and aluminum pipe.
    b. This also happens at grain boundaries along the pipe – after a certain amount of deterioration, a pressure surge splits the pipe.
    c. Plastic pipe does not solve the problem of above ground surface lines . . . since during very cold weather plastic pipes are easily broken due to shock-loads. In direct sunlight, plastic pipe deteriorates and then ruptures due to pressure surges. The high expansion-contraction coefficient of plastic also causes problems with riser locations and with leaks in very cold weather.

2. Most serious effects
    a. Pressure loss, therefore, poor distribution
    b. Increased flow may cause increased horsepower and motor overload
    c. Wastewater runoff problems may occur

3. Corrections
    a. Bury lines of appropriate material
    b. Drain aluminum lateral lines except when actually in use
    c. Coat steel parts
    d. Cathotic or anodic protection

B. *Problem — No flow from certain sprinkler nozzles*

1. Possible Causes
    a. Particles in wastewater too large
    b. No suction line screen on pump or suction screen may have developed a hole — perhaps due to partial plugging of the screen. Thus, sprinkler nozzles may be clogged, or riser may be clogged, or valve at end of lateral may be clogged, or screen at end of lateral may be clogged
2. Most serious effects
    a. No wastewater applied where sprinklers clogged . . .poor crops
    b. Pressure too high where sprinklers open, thus too high flow, causing crop damage and/or runoff
    c. High pressures can cause line damage
3. Corrections
    a. Adequate screening at the pumphouse
    b. Frequent and careful troubleshooting of system
    c. Proper maintenance and operation

C. *Problem — Adequate system management, particularly under adverse and severe weather conditions.*

1. Possible Causes
    a. Adequate management and operation of field irrigation systems often require dedication above and beyond the regular call of duty. Such as
        - changing valves in subfreezing weather
        - merely getting through the snow to where the valves are located
        - draining and flushing lines regularly, especially in winter
    b. Many standard M & O procedures are neglected during freezing temperatures, rain storms, or excessive snow days
    c. Working in wet grass up to one's waist isn't fun
2. Most serious effects
    a. Sprinklers clog; "lines" freeze and break
    b. Poor distribution, excess runoff
    c. All problems in all sections listed in this guide occur
    d. Wet ice is extremely slippery, especially on slopes, safety must be considered

3. Corrections
   a. Adequate salary for employees
   b. Adequate inspection with knowledgeable tips and assistance
   c. Probably most of all, however, is appropriate praise and respect for a job well done, i.e. – good management practices are needed to get the most out of the people who must maintain and operate a land treatment system

D. *Problem – Wind drifting spray onto neighbors' property.*

1. Possible causes
   a. May not have been considered in design
   b. Equipment designed to stop pumps when wind comes from specific direction or reaches specific speed may have malfunctioned
   c. Wind break planted for this purpose may not have grown to adequate height as yet
   d. Sprinklers may be operating at a higher pressure than that for which they were designed
   e. Traveling sprinkler may be permitted to move too close to the field border
   f. Original wind break may have been removed
2. Most serious effects
   a. This could vary anywhere from: farmer being happy to receive this water and nutrients, to
   b. The municipality being brought into a lawsuit by a neighbor who thinks he has more infections and problems than usual
3. Corrections
   a. Provide a larger buffer area in relation to neighboring properties
   b. Adjust or move distribution system to make sure spray remains within renovation area

III. Land Renovation Areas

A. *Problem – Water is flowing off application area, with or without erosion.*

1. Possible causes
   a. Related to renovation system:
      1. Infiltration rate too low – poor soils
      2. Soil surface sealed by solids, preventing infiltration
      3. Waste material forms mass on soil surface which destroys soil aggregation and prevents infiltration
   b. Related to distribution system
      1. Irrigation rate too high
      2. Broken line or deteriorated pipe
      3. Broken coupler latch, or displaced end plug
      4. Nozzles broken at other locations, thereby increasing pressure and flow at one application point

        - c. Too much rain in recent past
    - 2. Most serious effects
        - a. Wastewater runs off area without being renovated
        - b. Pollution of neighboring property, water supplies, etc.
    - 3. Corrections
        - a. Related to renovation system
            - 1. Strip crop area or put into permanent sod
            - 2. Terrace or use diversions
            - 3. Underdrain if soil is appropriate, etc.
            - 4. Keep soil well covered with grass or mulch
            - 5. Irrigate only sandy single grained soils
            - 6. Keep BOD low enough to be compatible with temp., soil, crop, etc.
        - b. Related to distribution system
            - 1. Condition can be corrected primarily by normal maintenance and operation
            - 2. Place sprinklers farther apart
            - 3. Decrease nozzle diameter of each sprinkler and increase the length of laterals and number of sprinklers
            - 4. Reduce irrigation rate
        - c. Don't irrigate if soil is saturated from natural rainfall
- B. *Problem – Erosion of Soil*
    - 1. Possible Causes
        - a. Most of the causes of Problem A, *Overflow off of land area,* can also cause soil erosion
        - b. Land remaining uncovered over long periods
        - c. Planting of the wrong crop for the soil
    - 2. Most serious effects
        - a. Loss of fertile soil
        - b. Poor quality runoff, downstream water quality problems, including nutrients and pesticides
        - c. Deposition of soil in ditches, canals and downstream waterways
    - 3. Corrections
        - a. Most of the corrections for Problem A may be applicable
        - b. If problem is with crop or soil, consult county agent or other agricultural specialist
- C. *Problem – Crop that was being irrigated is dead*
    - 1. Possible causes
        - a. Too much water applied
        - b. Too much of certain nutrients applied, i.e. crops need certain nutrients and only certain amounts of these, too much of most any nutrient will kill the crop

        c. Too much of any type detrimental chemical – weed killers, etc. through treatment plant – from area runoff or disposed of through drains

    2. Most serious effects

        a. "Dead crop makes a darn poor living filter," i.e., the system just isn't working
        b. Dead crop adds to BOD load
        c. Infiltration is decreased – runoff can occur or increase
        d. Nutrients are not removed
        e. Unsightly area – neighbors concerned
        f. Excess odors – neighbors concerned

    3. Corrections

        a. Close monitoring of all inflows to the treatment plant, including industrial wastes
        b. Monitor plant effluent for toxic materials
        c. Reduction of high flow rates
        d. Modification of nutrient balance applied to the crop
        e. Consult with county agent or other agricultural specialist

D. *Problem – Areas of Water Pooling or Sink Holes*

    1. Possible Causes

        a. Broken mainline
        b. Inoperative valve, mechanical or electrical malfunction
        c. Electrochemical corrosion
        d. Insufficient pressure to seal portable pipe
        e. Improper choice of site in design or adding water beyond design limits
        f. Any malfunction or improper operation that causes an excess of wastewater to be discharged

    2. Most serious effects

        a. Dangerous to farm operating equipment
        b. Unsafe to man and animals, especially before final cover on surface has fallen in
        c. Pollution of groundwater in general or to private, town, or industrial water source which usually ends in law suit
        d. Continued loss of renovation effect, possible loss of use of entire system, which is tremendous financial loss

    3. Corrections

        a. Inspection and evaluation by professional persons with experience and expertise in this area
        b. Install adequate surface drainage early in construction or very early in operation
        c. Sound maintenance and operation, with lots of good common sense

E. *Problem – Small corn ears, cobs not filled out with kernels, yellow corn leaves, crop not responding as it ought.*

1. Possible causes
    - a. Too much water applied – same as before
    - b. Too little nutrients applied
        - crop does not have enough nutrients to go to maturity
        - crop too thick for nutrients applied
        - too much grass in corn, competition
    - c. Nutrient applied too early
        - then irrigation water leached nutrients through soil into groundwater or out into stream (this nutrient loading may be worse than original effluent).
    - d. Nutrients may have been of wrong type for time they were applied
2. Most serious effects
    - a. Poor economical balance
    - b. Increased pollution per nutrient leaching
    - c. Detrimental outlook effect on farmer, operator, etc., thus have "don't care" attitude in other work
3. Corrections
    - a. Advice from County Agent, S.C.S., and/or professional agricultural consultants with this type experience
    - b. Good maintenance and operation of entire distribution and renovation system

REFERENCES – LAND TREATMENT

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Land Application of Sewage Effluents and Sludges: Selected Abstracts. EPA Technology Series, June, 1974.

Recycling Municipal Sludges and Effluents on Land. National Association of State Universities and Land-Grant Colleges, July, 1973.

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Sopper, W.E., and L. T. Kardos, Editors. Recycling Treated Municipal Wastewater and Sludge Through Forest and Cropland. IN: Symposium Proceedings at University Park, Pa. The Pennsylvania State University Press, August, 1973. 479 pages.

Pound, C. E. and R. W. Crites. Wastewater Treatment and Reuse by Land Application. Vol. I and II. EPA, August, 1973. Vol. I – 81 pages, and Vol. II – 251 pages.

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Myers, Earl A. Management of Land Disposal Systems for Adequate Renovation. AIChE Conference Proceedings, Chicago, Ill, May, 1975. 20 pages.

Sullivan, R.H., M. M. Cohn, and S.S. Baxter. Survey of Facilities Using Land Application of Wastewater. American Public Works Association. EPA, July, 1973. 377 pages

Butler, Robert M. et al. Spray-Irrigation Disposal of Wastewater. Sp. Circ. 185. Ag. Ext. Suc. The Pennsylvania State University, University Park, Pa. 1974. 17 pages.

Myers, Earl A., and Edward M. Burt. Automation of Wastewater Land Application Systems. Sprinkler Irrigation Association Conference Proceedings, Atlanta, Ga., February, 1975. 12 pages

Malhotra, Sudarshan K. and Earl A. Myers. Design, Operation, and Monitoring of Municipal Land Irrigation Systems in Michigan. WPCF Conference, Denver, Co, October, 1974. 25 pages.

LESSON – CHLORINATION

Instructor Overview of Lesson

Entry Level Behavior: Students will have had University training in Sanitary Engineering, waste treatment and/or related sciences or equivalent in experience and training. Some field experience in inspecting treatment plants, but none in operating waste treatment facilities.

As a prerequisite to this course, it is recommended that the student will be able to –

1. Identify treatment plant process units
2. Describe treatment plant process units and equipment in technical terms
3. Identify and explain the purpose of components of treatment plant process units, how they work and why they are important to the overall process
4. Describe the normal operating procedures for treatment plant process unit components
5. Identify when treatment plant process units are not operating properly.

Instructor Objectives: The principal instructor objectives for this lesson are:

1. To discuss the various uses of chlorine at a wastewater treatment plant, including troubleshooting applications
2. To review the properties and hazards of chlorine
3. To apply the Process of Troubleshooting to Chlorination Systems

References: Note list of references included with Student Notebook materials.

Total Length of Lesson: 90 minutes for 2 lesson subdivisions.

LESSON OVERVIEW

Subdivision Title & Time	Major Student Objectives	Key Points & Content	Approach	Materials
1. Uses of Chlorine in a Treatment Plant	1. List and identify uses of chlorine in a treatment plant.	1. Chlorine requirements are under reconsideration by EPA.	1. Follow lesson outline, using word slide series.	1. Student Notebook pages – on Uses of Chlorine and Operation of Facilities.
35 Minutes	2. Describe key points of using chlorine for disinfection, controlling odors, preventing sewage decomposition, upgrading operations and delaying effluent BOD.	2. Chlorine applicable to a variety of plant uses.	2. Section 1 – seek student input, record responses on chalkboard.	2. Slide series and slide key – 9 word slides.
	3. List principal chlorine properties.	3. Caution should be used before applying chlorine to upgrade operations.	3. Use references to Student Notebook material.	
	4. Describe the hazards, precautions and proper handling for chlorine.	4. Troubleshooter should know chlorine properties, and how to use it.		
2. Troubleshooting Chlorination	1. Relate the Process of Troubleshooting to chlorination.	1. Use of the Process of Troubleshooting for Chlorination problems.	1. Follow lesson outline, using Notebook materials.	1. Word Slide CH-10.
55 Minutes	2. Identify equipment, points of concern, and possible malfunctions.	2. System points of concern, and malfunctions.	2. Section IV, class works in groups to discuss and complete Troubleshooting Guide.	2. Process of Troulbeshooting Chart.
	3. Relate specific chlorination problems to chlorination system malfunctions.		3. Section V, class dicscussion of Troubleshooting Guide.	3. Student Notebook, Tables, p CH-3 and Troubleshooting Guide, p CH-4. 4. EPA Manual, "Evaluating . . ." 5. Optional – specific details on chlorination equipment.

LESSON – CHLORINATION

Presentation Options for Course Director

The 90 minute lesson, Chlorination, is one of the less essential lessons of this course. While chlorination is obviously a very important wastewater treatment operation, it has been found by the developers of this course that most students with the proper entry level behavior are sufficiently well-grounded in the fundamentals of chlorination. Therefore, this lesson is *not* designed to be a review of the fundamentals and the properties of chlorine, but rather attempts to relate troubleshooting plant problems to the application of chlorine in a treatment plant.

If there is limited time for the presentation of this course, this lesson should be a prime candidate to be excluded. If it is presented, there would be some options available to the Course Director on the approach to be used.

Subdivision 1 – Uses of Chlorine in a Treatment Plant: The instructor may go into more detail on the various chlorine uses, if desirable. Section VI, Properties and Hazards of Using Chlorine, should not be expanded upon, inasmuch as this is standard material for which many outside references can be found.

Subdivision 2 – Troubleshooting Chlorination: For some students, it may be desirable to go into the details of chlorination equipment. This may be done by a) obtaining detailed material from chlorinator manufacturers and distributing the material to the class, or b) visiting a treatment plant and inspecting the chlorination equipment. If either approach is used, this subdivision must be lengthened in time.

CHLORINATION

LESSON PLAN – SUBDIVISION 1 **TIME: 35 MINUTES**

Title: Uses of Chlorine in a Treatment Plant

Instructor Objectives: To discuss the various uses of chlorine at a wastewater treatment plant, including applications of chlorine that may be of value to a troubleshooter in solving plant problems. To briefly review the properties and hazards of chlorine.

Student Objectives: As a result of this lesson subdivision, students will be able to do the following:

1. List the various uses of chlorine in a treatment plant
2. Identify uses of chlorine of value in troubleshooting plant problems
3. Discuss the key points in using chlorine in disinfecting wastewater plant effluents
4. Describe the uses of chlorine in controlling plant odors and preventing sewage decomposition
5. Utilize chlorine to upgrade plant operations and correct operational problems
6. Discuss the use of chlorine to reduce or delay effluent BOD
7. List the principal properties of chlorine
8. Describe the hazards of chlorine, and safety precautions to take to avoid those hazards
9. Observe proper usage and handling of chlorine in a treatment plant.

Training Materials:

Student Notebook Pages CH-1 and 2, Tables on the Uses of Chlorine and the Operation of Chlorine Facilities

Slide Series of 9 Word Slides and Slide Key

Classroom Set-up:

A normal classroom set-up will be required

Students should be seated with their student groups

35 mm carousel slide projector with remote control

Large screen (8 ft x 10 ft)

Chalkboard or easel

Pointer

Subdivision Schedule:

Within the 35 minute time period, the following schedule should be observed in presenting the lesson plan outline

TIME	SUBJECT
0 – 5 Minutes	Identify Chlorine Uses
5 – 10 Minutes	Disinfection
10 – 15 Minutes	Prevention of Sewage Decomposition
15 – 20 Minutes	Upgrading Plant Operations
20 – 25 Minutes	Reduction of Delay of BOD
25 – 35 Minutes	Properties and Hazards of Using Chlorine

Subdivision Approach:

The instructor is to rely upon the lesson outline, the slide series and key, and the Student Notebook

Section I requires student input, with the recording of student responses at the chalkboard by a student recorder asked to go to the board for that purpose

Student discussion should be encouraged throughout the lesson subdivision

LESSON OUTLINE

I. Identify Chlorine Uses (5 minutes)

  A. Have students suggest all of the treatment plant uses of chlorine they know of

  B. Emphasize uses which can serve as a tool to the troubleshooter for solving plant problems

  C. Have student recorder at chalkboard arrange responses according to four principal categories of chlorine use:

    1. Disinfection
    2. Prevention of sewage decomposition
    3. Aid in plant operation
    4. Reduction or delay of BOD

  D. Summarize Uses – Notebook Page CH-1

    1. Note tabulation of chlorine cases. Notebook page CH-1

II. Disinfection (5 minutes)

  A. Purpose – to remove pathogenic organisms from sewage plant effluent

    1. Requirements for chlorination depend on residual established in NPDES permit, or by local or state authority

  B. Degree of use

    1. In 1973, 48% of U.S. treatment plants disinfected, virtually all by chlorination
    2. Alternatives to chlorination are being evaluated by EPA, particularly in light of recent chlorine shortages
      a. Ozonation – costly, and requires more power
      b. Ultraviolet light
      c. Bromine Chloride

  C. Application

    1. Must be continuous process to reach all organisms

KEY POINTS & INSTRUCTOR GUIDE

Guide: Emphasize discussion and input from students. Have one student record class inputs at chalkboard.

Refer class to Student Notebook page CH-1.

Key Point: Chlorine requirements have been under reconsideration by EPA.

Instructor may want to discuss specific requirements in the area in which the course is being presented if:

a. He is aware of present requirements.
b. It is pertinent to the discussion.

USES AND DOSAGE OF CHLORINE IN A WASTEWATER TREATMENT PLANT

Type of Chlorine Use		Specific Application	Dosage in PPM	Recommended Residual in PPM
1. Disinfection	A.	Remove pathogenic organisms from treatment plant	Depends on local conditions and permit requirements	Depends on local conditions and permit requirements
2. Prevention of Sewage Decomposition	A.	Odor Control at:		
		1. Sewers and influent point	1. 1.5 – 10	0
		2. Overload secondary treatment facilities	2. 5 – 10	0
	B.	Protection of plant structures by controlling corrosion		
	C.	Sludge thickening		
3. Upgrading Plant Operations	A.	Sedimentation		
	B.	Trickling filters		
		1. Odor control	1. 2 – 6	0
		2. Filter ponding & clogging	2. 5 – 40	1 – 2
		3. Trickling filter flies	3. 3 – 10	0.1
	C.	Activated Sludge		
		1. Sludge bulking control	1. 2 – 8	0
		2. Sludge thickening	2. Variable	1.0
	D.	Imhoff tank foaming	3 – 15	0
	E.	Grease Separation		
4. Reduction or Delay of BOD	A.	Apply during overload or emergency conditions to prevent oxygen depletion in receiving waters	6 – 12	0.2 – 0.5

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

2. Must be rapidly mixed with effluent flow, and held for 15 minutes, by contact tank or outlet sewer

3. Generally dose: 100 to 200 lbs per million gallons

D. Upgrading disinfection at plants

1. Where stringent standards must be met
   a. Will often require nitrification of ammonia nitrogen
   b. Or, extra long post chlorination retention basin

2. Less stringent requirements can be achieved by
   a. Higher chlorine dosages
   b. Improving mixing and/or longer contact time

E. Chlorinating Chemicals

1. Liquid elementary chlorine most frequently used, most cost-effective

2. Calcium and sodium hypochlorate salts can be used
   a. Cannot be fed as a dry chemical

III. Prevention of Sewage Decomposition (5 minutes)

A. General applicability

1. Chlorine effectively acts as an oxidizing agent which, when applied properly, can prevent the decomposition of sewage, and thus help solve the following in-plant problems

2. Cite an example of the use of chlorine where possible

Guide: Instructor should cite actual example ... i.e., "Back in Oshkosh in '64 we had an odor problem which ... "

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
B. Odor Control	
1. "CAUSES OF PLANT ODORS"	SLIDE CH 1 (word)
• Sewage decomposition in sewers and pump stations	
• Septic Sewage	Guide: Show next slide to show why chlorine is often used to control odors.
• Overloaded facilities — inadequate aeration	
• Sludge treatment	
2. "CHLORINE USED TO CONTROL ODORS BECAUSE"	SLIDE CH 2 (word)
• It's highly effective	
• Facilities available at many plants	
• Operators have experience using chlorine	
3. Impact of chlorination on odors	Guide: Briefly describe alternatives to chlorine using the next slide.
a. Retards biological actions that produce odors	
b. Oxidizes odorous sulfur compounds	
4. "ALTERNATIVES TO CHLORINE FOR ODOR CONTROL"	SLIDE CH 3 (word)
• Changes in operational procedures	
• Other chemicals — ozone, lime, powdered carbon	
• Collection and treatment of noxious gases	
C. Protection of plant structures	
1. Decomposed sewage may lead to H_2S, but no odors due to location or low concentration	
a. Serious corrosion may occur in concrete mortar or paint	
b. Structural damage or shutdown could occur	
2. H_2S corrosion controlled with chlorine	
a. Apply similar to use for odor control	
b. Less chlorine needed than for odor control	
D. Sludge Thickening	
1. Septic sludge may result from excess activated sludge or raw sludge in tanks or thickeners	

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

a. Apply chlorine to incoming sludge

b. Maintain chlorine residual of 1 mg/l

IV. Upgrading Plant Operations (5 minutes)

A. Chlorine can be a *tool* to the operator and troubleshooter to help upgrade treatment plant operations. HOWEVER, it is seldom the *preferred* method of bringing about these improvements, and alternatives should be carefully considered before chlorine is used for the following purposes:

Key Point: Caution should be used before applying chlorine to upgrade plant operations.

B. Sedimentation Improvement

1. Prechlorination increases wastewater coagulation and settling, produces a heavier sludge

   a. Usually not cost effective for this purpose alone

   b. Where prechlorination is desired for other purposes, better settling results are an added benefit

C. Trickling Filters

1. "USES OF CHLORINE FOR TRICKLING FILTERS:

   - Odor control
   - Control of filter flies
   - Control of ponding and clogging

SLIDE CH-4 (word)

2. Control of Trickling Filter Flies

   a. Psychoda fly larvae and pupae develop at upper surface of filter

   b. Chlorine dose induces sloughing of film at upper surface, thus eliminates flies

3. Control of Trickling Filter Ponding and Clogging

   a. Caused by excessive filamentous growths and accumulations of solids

   b. Continuous chlorination may aid in control

   c. If filter is overloaded, chlorine is of no value

   d. Some filters, intermittent chlorination works best

LESSON OUTLINE

D. Activated Sludge Bulking

   1. Chlorinate return activated sludge

      a. Apply where 2 to 3 minutes of mixing can occur prior to discharge to aeration basin

      b. Chlorine dose varies in relation to sludge volume index, reduce daily as sludge volume is reduced

   2. Some plants, intermittent chlorination maintains slow sludge volume index

   3. Often turbidity of plant effluent increases temporarily when return sludge is chlorinated

   4. Also reduces immediate oxygen requirement of return activated sludge

E. Imhoff Tank Foaming

   1. Can sometimes be controlled by continuous addition of chlorine

F. Grease separation

   1. Chlorine facilitates separating of grease from wastewater where this is a problem

V. Reduction or Delay of BOD (5 minutes)

   A. Use of chlorine as a *temporary* means of preventing serious oxygen depletion in streams should be stressed

   B. Used in conditions of overload, extreme low stream flow, or intermittent loadings

      1. Normally chlorination is not economically practical for reducing effluent BOD

      2. High residual delays and reduces oxygen demand in receiving stream

KEY POINTS & INSTRUCTOR GUIDE

LESSON OUTLINE

a. Allows more time and distance for dilution

b. May harm aquatic life

3. Does have value under emergency conditions

C. Summary on Uses of Chlorine

1. Disinfection should be the only routine use of chlorine in a treatment plant

2. Alternative methods of solving problems should be considered in addition to chlorine

3. Chlorine does have some "last resort" troubleshooting value

4. Extreme care must be exercises in using chlorine – as discussed in the following section

VI. Properties and Hazards of Using Chlorine (10 minutes)

A. Troubleshooters and operators must know the properties and hazards of chlorine if they are to be able to use it

1. Plant operators should receive safety and first-aid training before using chlorine

2. Troubleshooters should receive same training if possible

3. "PROPERTIES OF CHLORINE"

- Greenish yellow gas
- 2½ times heavier than air
- Slightly soluble in water
- Pungent and irritating odor
- Pressure changes with temperature

4. "BEHAVIOR OF CHLORINE"

- Non-flammable
- Non-explosive
- Non-conductive electrically
- Corrosive in presence of moisture
- Highly reactive
- Oxidizing agent

KEY POINTS & INSTRUCTOR GUIDE

Guide: The next two slides to discuss the properties of chlorine.

SLIDE CH-5 (word)

SLIDE CH-6 (word)

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
B. Health Hazards and Precautions	Use Slide CH-7 to describe health hazards of chlorine.
1. "HEALTH HAZARDS OF CHLORINE" • Excessive amount is fatal • Not cumulative • Irritating to eyes and skin • Respiratory system is vulnerable	SLIDE CH-7 (word)
2. "EMERGENCY EQUIPMENT TO HAVE" • Gas mask oustide chlorine room • Alkali or alkali solution • Ammonia water • Air pack • Goggles and boots	SLIDE CH-8 (word) Note: Gas pack can substitute for gas mask. Ammonia should be reagent type, not houehold type.
3. "FIRST AID FOR CHLORINE EXPOSURE" • Flush eyes and skin with water • Artificial respiration if necessary • Move patient outside • Keep warm • Call physician	SLIDE CH-9 (word) Note: Patient should be moved upwind. Milk or oxygen is beneficial if available.
C. Troubleshooter should look for the following: 1. Proper venting in chlorine room – venting from bottom of room is essential 2. Gas mask outside door of chlorine room 3. Good maintenance of chlorine room and its equipment 4. Chlorine cylinders secured tightly 5. No chlorine leaks detectable	
D. Troubleshooter should know how to use chlorine 1. Emergency procedures 2. Operation of chlorine facilities	Refer class to Student Notebook, p. CH-2 – briefly review material.

CHLORINATION

LESSON PLAN – SUBDIVISION 2 **TIME: 55 MINUTES**

Title: Troubleshooting Chlorination

Instructor Objectives: To relate the Process of Troubleshooting to chlorination, and to the specific points of concern and malfunctions in chlorination systems.

Student Objectives: As a result of this lesson subdivision, students will be able to do the following:

1. Relate the Process of Troubleshooting to problems in chlorination
2. Identify types of chlorination equipment
3. Describe points of concern in chlorination systems
4. Test chlorine application malfunctions and deficiencies
5. Relate chlorine system points of observation and points of malfunction to specific problems

Training Materials:

One word slide (CH-10) and key

Chart, The Process of Troubleshooting

Student Notebook page CH-3, Tables on Chlorine System Points of Concern and Typical Malfunctions

Chlorination Troubleshooting Guide, Student Notebook page CH-4, to be used for student group exercise

Optional Specific details on chlorination equipment, to be obtained by instructor from chlorinator manufacturers

EPA Manual, "Evaluating the Performance . . . ." pp 89-108

Classroom Set-up:

A normal classroom set-up will be required. Students must be seated with their student groups

35 mm carousel slide projector with remote controls

Large screen (8 ft x 10 ft)

Chalkboard or easel

Pointer

Subdivision Schedule:

Within the 55 minute time period the following schedule should be observed in presenting the lesson plan outline:

TIME	SUBJECT
0 – 5 Minutes	The Process of Troubleshooting
5 – 10 Minutes	Chlorine Application Equipment
10 – 15 Minutes	Chlorination System Points of Concern
15 – 40 Minutes	Troubleshooting Guide to Chlorination
40 – 50 Minutes	Discussion of Troubleshooting Guide
50 – 55 Minutes	Questions and Summary

Subdivision Approach:

Sections I through III, follow lesson plan outline, using Notebook materials and word slide (CH-10) where indicated.

Section IV, Students work in student groups to complete Troubleshooting Guide provided as Notebook page CH-4. Student discussion is to be encouraged by instructor. EPA Manual may be used to assist students.

Section V, Class discussion on Troubleshooting Guide, led by instructor who calls on each group, one by one, for their contribution toward completing the Guide.

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

I. The Process of Troubleshooting (5 minutes)

   A. Troubleshooting problems in chlorination are very equipment oriented. Things an inspector must know include:

      1. Type and design of specific equipment used – best sources of information are the manufacturers

      2. Components of a chlorination system – points of concern where trouble may occur

      3. Key elements in Process of Troubleshooting

         a. Element 1-c – key points for observation in chlorination system
         b. Element 1-d – Data needs - what data are most likely to be needed in troubleshooting chlorination systems?
         c. Element 1-e – Analyses that need to be performed
         d. Element 2 – Alternatives for solving chlorination system problems

Guide: Refer students to Process of Troubleshooting Chart in Student Notebook.

Key Point: Stress the use of the Process of Troubleshooting in Solving Chlorination Problems.

II. Chlorine Application Equipment (5 minutes)

   A. Types

      1. Dry feed gas chlorinators. Application of dry chlorine gas – used only where water under pressure is not available

      2. Solution feed gas chlorinators. Chlorine gas-water solution applied to sewage, vacuum type chlorinators are preferable

      3. Hypochlorinators. Feeds solution by diaphragm metering pumps

III. Chlorination System Points of Concern (5 minutes)

   A. Chlorine room – needs to be inspected for safety and for adequate operating ability

Refer class to Student Notebook page CH-3, Table on Chlorination System Points of Concern.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
B. Chlorine cylinders – must be properly secured	
C. Chlorine scales – must be operational	
D. Chlorine supply line	
E. Chlorinator system 1. Pressure reducing valve and shutoff valve 2. Feed rate indicator 3. Pressure gauge 4. Variable orifice for feed rate control 5. Vacuum regulating valve 6. Injector or vacuum producing device 7. Control systems	
F. Chlorine contact tanks – may be upgraded to improve disinfection by – 1. Improving mixing characteristics of the basin 2. Eliminating short circuiting 3. Improving chlorine diffuser system 4. Lengthening contact time	Illustrate upgrading of Chlorine Contact Tanks by showing Slide CH-10.
"UPGRADING CHLORINE CONTACT TANKS – IMPROVE DISINFECTION" • Improve mixing characteristics • Eliminate short circuiting • Improve chlorine diffuser system • Lengthen contact time	SLIDE CH-10 (word)
G. Effluent sampling point – indicates improper disinfection	
H. Downstream receiving water – indicates inadequate disinfection or chlorine residual.	
IV. Troubleshooting Guide to Chlorination (25 minutes)	
A. Chlorine application malfunctions and deficiencies 1. Insufficient chlorine gas pressure at the chlorinator 2. No chlorine gas pressure at the chlorinator 3. Icing of rotameter tube and supply line	Refer class to Student Notebook list of malfunctions, page CH-3.

LESSON OUTLINE

4. Absence of chlorine flow
5. Leaking of chlorine gas
6. Closing of external chlorine pressure reducing valve
7. Insufficient chlorinator feed rate
8. Excessive chlorine odor at point of application
9. Inadequate chlorine residual at sampling point
10. Wide variation in chlorine residual
11. Improper control at residual analyzer
12. Coliform count fails to meet required standards
13. Chlorine residual exceeds toxicity requirements

B. Assign students to work in predetermined student groups for the purpose of constructing a troubleshooting guide for chlorination

C. Have student groups complete the troubleshooting guide by listing, for each chlorine problem listed

1. Possible points of observation in the chlorination system
2. Possible points of malfunction
3. Note that the first line low gas pressure, is already completed as an example for the students on using the chart
4. Students may use EPA Manual, "Evaluating the Performance of Wastewater Treatment Plants," pp 89-108, to assist them, if necessary

D. After 25 minutes, have the class complete the troubleshooting guide and prepare to discuss the results

V. Discussion of Troubleshooting Guide (10 minutes)

A. Call on each student group, in turn, to report on one line of the troubleshooting guide for chlorination

KEY POINTS & INSTRUCTOR GUIDE

Refer class to Student Notebook page CH-4, Chlorination Troubleshooting Guide.

Guide: Class should be advised that the groups should discuss the various possible malfunctions that may occur for each problem on the troubleshooting guide.

Note: The section on chlorination in the EPA Manual is one of the most thorough of the entire document.

Guide: The purpose of this section is to have the student groups report on the make-up of the troubleshooting guide.

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

B. Instructor should attempt to call on as many groups as possible within the 10 minute time allotted

C. After a group reports on a line of the guide, give the class the opportunity for discussion, before going on to the next group

D. After 10 minutes, suggest to the students that they complete the guide on their own time, using the EPA manual as a reference

VI. Questions and Summary (5 minutes)

A. Briefly summarize the lesson on Chlorination, and answer any questions received from the class

STUDENT NOTEBOOK MATERIALS

The following materials are included in Section 13 of the Student Notebook, Chlorination. The Notebook is distributed to students at the start of the course, and is available to them as a reference material throughout the course. Some of these materials are to be used by the instructor as an integral part of the lesson.

Index of Notebook Materials

PAGES	MATERIAL	USE IN LESSON
CH – 1	Uses and Dosage of Chlorine	Reference by instructor, Subdivision 1, Section I
CH – 2	Operation of Chlorine Facilities	Reference by instructor, Subdivision 1, Section VI
CH – 3	Chlorine System Points of Concern and Typical Malfunctions and Deficiencies	Reference by instructor, Subdivision 2, Section III
CH – 4	Chlorination Troubleshooting Guide	Subdivision 2, Section IV To be completed as class exercise by student groups
CH – 5	References	

USES AND DOSAGE OF CHLORINE IN A WASTEWATER TREATMENT PLANT

Type of Chlorine Used		Specific Application	Dosage in PPM	Recommended Residual in PPM
1. Disinfection	A.	Remove pathogenic organisms from treatment plant	Depends on local conditions and permit requirements	Depends on local conditions and permit requirements
2. Prevention of Sewage Decomposition	A.	Odor Control at:		
		1. Sewers and influent point	1. 1.5 – 10	0
		2. Overload secondary treatment facilities	2. 5 – 10	0
	B.	Protection of plant structures by controlling corrosion		
	C.	Sludge thickening		
3. Upgrading Plant Operations	A.	Sedimentation		
	B.	Trickling filters		
		1. Odor control	1. 2 – 6	0
		2. Filter ponding & clogging	2. 5 – 40	1 – 2
		3. Trickling filter flies	3. 3 – 10	0.1
	C.	Activated Sludge		
		1. Sludge bulking control	1. 2 – 8	0
		2. Sludge thickening	2. Variable	1.0
	D.	Imhoff tank foaming	3 – 15	0
	E.	Grease Separation		
4. Reduction or Delay of BOD	A.	Apply during overload or emergency conditions to prevent oxygen depletion in receiving waters.	6 – 12	0.2 – 0.5

OPERATION OF CHLORINE FACILITIES

OPERATION INFORMATION

Do not heat cylinders
Do not put water on leaks
Do not run lines through differing temperature zone
Do not immerse cylinder in water
Do not put mask with chlorine
Do not use rubber hose for chlorine lines

Do use proper chlorine wrench
Do read cylinder tags
Do ventilate chlorine room
Do roll leaking cylinder to emit gas not liquid
Do learn emergency procedures
Do always use new washers
Do open cylinder completely

CONNECTIONS

Use yoke and adapter
Use copper tubing type K
Avoid using aluminum or stainless steel
Carbon steel schedule 80 seamless may be used

EMERGENCY PROCEDURES

Evacuate the area
Apply gas mask
Locate leak with ammonia mist or rag
Shut off chlorine
Shut off chlorinator if connected
Position cylinder to emit gas not liquid
Tighten threaded fittings if leaking
Apply proper safety kit device
Disconnect cylinder and remove
Call supplier and advise

CHLORINATION SYSTEM POINTS OF CONCERN

A. Chlorine room

B. Chlorine cylinders

C. Chlorine scales

D. Chlorine supply lines

E. Chlorinator system

  1. Pressure reducing valve and shutoff valve
  2. Feed rate indicator
  3. Pressure gauge
  4. Variable orifice for feed rate control
  5. Vacuum regulating valve
  6. Injector or vacuum producing device
  7. Control systems

F. Chlorine contact tanks

G. Effluent sampling point

H. Downstream receiving water

TYPICAL CHLORINE APPLICATION MALFUNCTIONS AND DEFICIENCIES

1. Insufficient chlorine gas pressure at the chlorinator
2. No chlorine gas pressure at the chlorinator
3. Icing of rotameter tube and supply line
4. Absence of chlorine flow
5. Leaking of chlorine gas
6. Closing of external chlorine pressure reducing valve
7. Insufficient chlorinator feed rate
8. Excessive chlorine odor at point of application
9. Inadequate chlorine residual at sampling point
10. Wide variation in chlorine residual
11. Improper control at residual analyzer
12. Coliform count fails to meet required standards
13. Chlorine residual exceeds toxicity requirements

CHLORINATION TROUBLESHOOTING GUIDE

To be completed by student groups and class discussion

PROBLEM	POSSIBLE POINTS OF OBSERVATION	POSSIBLE POINTS OF MALFUNCTION
1. Low gas pressure	a. Pressure gauge b. Supply line	a. Pressure reducing valve b. Supply line
2. Zero gas pressure		
3. Icing		
4. Absence of chlorine flow		
5. Leaking of chlorine flow		
6. Closing of pressure reducing valve		
7. Insufficient feed rate		
8. Excessive chlorine odor		
9. Low chlorine residual		
10. Variation in chlorine residual		
11. Improper control at residual analyzer		
12. High coliform count		
13. Excessive chlorine residual		

References: Notebook Page CH-3
EPA Manual "Evaluating the Performance of Wastewater Treatment Plants," pp 89-108

REFERENCES

Layton, R.F. Disinfection of Wastewaters. Journal of the Missouri Water and Sewerage Conference, 1975.

Chlorine Institute Manual, Bulletin 70-9001. The Chlorine Institute.

URS Research Company. Procedural Manual for Evaluating the Performance of Wastewater Treatment Plants. U.S. Environmental Protection Agency.

White, G.C. Disinfection: The Last Line of Defense for Potable Water. Journal American Water Works Association, G7, 410, 1975.

LESSON – CLOSING

Instructor Overview of Lesson

Entry Level Behavior: Students will have had University training in Sanitary Engineering, waste treatment and/or related sciences or equivalent in experience and training. Some field experience in inspecting treatment facilities, but none in operating waste treatment facilities.

As a prerequisite to this course, it is recommended that the student will be able to –

1. Identify treatment plant process units
2. Describe treatment plant process units and equipment in technical terms
3. Identify and explain the purpose of components of treatment plant process units, how they work and why they are important to the overall process
4. Describe the normal operating procedures for treatment plant process unit components.
5. Identify when treatment plant process units are not operating properly

Instructor Objectives: The principal instructor objectives for this lesson are:

1. To present a final quiz which will evaluate the level of understanding gained by the students from the course
2. To review course content and approach
3. To provide opportunity for objective evaluation and verbal discussion of the course
4. To recognize the student completion of the course

Total Length of Lesson: 1 Hour for 3 (one optional) subdivisions

LESSON OVERVIEW

Subdivision Title & Time	Major Student Objectives	Key Points & Content	Approach	Materials
1. Final Student Assessment 30 Minutes	1. Demonstrate knowledge of The Process of Troubleshooting	1. Quiz on troubleshooting treatment plant operations	1. Instructor supervises quiz	1. Final student assessment quiz 2. Answer Key
2. Summary of Course 15 Minutes	1. Summarize purpose & content of course	1. Purpose & objectives 2. The Process of Troubleshooting 3. Review of Lesson Subjects	1. Follow lesson outline 2. Seek input and comments from students	1. Student Notebook pages OV-2 and ET-1 2. Process of Troulbeshooting Chart
3. Evaluation and Critique (Optional) 30 Minutes	1. Provide evaluation and critique of course	1. Written evaluation 2. Verbal critique	1. Use prepared written evaluation form 2. Verbal discussion	1. Written evaluation form must be prepared by Course Director
4. Awarding of Certificates 15 Minutes	1. Receive recognition for completing course	1. Certificates or documents recognizing student participation in course	1. Course Director expresses appreciation to students 2. Course Director awards certificates	1. Certificates

CLOSING

LESSON PLAN – SUBDIVISION 1 **TIME: 30 MINUTES**

Title: Final Student Assessment

Instructor Objectives: To present a final quiz to the students which will evaluate the level of understanding gained from this course in Troubleshooting O&M Problems in Wastewater Treatment Plants

Student Objectives: To pass the quiz and demonstrate knowledge of The Process of Troubleshooting.

Training Materials:

A copy of the Final Student Assessment is provided with the course materials. Copies should be made in advance of the course presentation for each member of the class and distributed at the start of the student assessment period

The assessment quiz contains 6 pages, which include space for answering all of the questions

An answer key to the final assessment is provided with the course materials

Classroom Set-up:

A normal classroom set-up will be required. Students should be seated at tables or desks, with enough room to work on the quiz comfortably, and without interference from other students

Subdivision Approach:

1. Announce the quiz and distribute papers. Allow a full 30 minutes
2. Announce that all answers should be given on the question sheets handed out
3. The instructor (Course Director) should be present in the classroom during the exam to answer questions
4. Note to the class that Part III may be done "open book," that they may use any materials supplied to them in the course
5. After 30 minutes, collect all papers. Tell students to make sure their names are on each of the 6 sheets
6. Course Director should grade the quizzes using the answer key
7. The use of the results of the quiz should be at the discretion of the Course Director. It can be used for:
   a. Determining who has successfully completed the course
   b. Determining how well the class as a whole has responded to the course and the instructor
   c. Any other legitimate educational purpose

DATE ____________________ NAME ____________________

FINAL STUDENT ASSESSMENT

TROUBLESHOOTING OPERATING AND MAINTENANCE PROBLEMS AT MUNICIPAL WASTEWATER TREATMENT FACILITIES

You have 30 minutes to complete this three-part quiz.

PART I: Identify and discuss briefly the five (5) principal elements in the Process of Troubleshooting. (20 points).

1)

2)

3)

4)

5)

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PART II: Answer the following questions by checking (√) either the "True" or the "False" column, corresponding to the question. (55 points).

	TRUE	FALSE	
ET			1. Plant logs and records are the most reliable sources of information for the troubleshooter.
MB			2. A wastewater treatment plant is a unique enterprise with unique management problems.
SH			3. Although problems with solids in treatment plants are frequent, they seldom lead to other problems.
OL			4. Modification of design is the most effective alternative for upgrading oxidation lagoons.
AS			5. The activated sludge process varies in size, offers flexibility, produces high quality effluent, and requires little or no process controls.
LP			6. Laboratory practices can cause as well as help to solve many treatment plant problems.
PT			7. The purpose of pretreatment is to prepare inflowing wastewater in order to maximize downstream plant performance.
TF			8. Climate is a factor in considering the peformance of a trickling filter plant.
OV			9. The overall objective of this course has been to improve the enforcement aspects of PL 92-500.
CA			10. Generally, chemical additives are used a conventional plants for odor control.

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	TRUE	FALSE	
SH			11. A "stuck" or "sick" digester can be described as doing the same things as an upset stomach.
CH			12. Improving the chlorine diffuser system is one method of upgrading chlorine contact tanks.
AS			13. Sludge age is defined as the pounds of suspended solids in the aeration system divided by pounds of suspended solids in the primary effluent per day.
LT			14. The four elements of a land treatment system are: a) weather, b) land area, c) distribution, & d) transportation.
AS			15. A rising sludge blanket should alert the troubleshooter to a "septic" condition.
FM			16. The troubleshooter should characterize "flows" as linkages between plant processes.
AS			17. The most common sludge problems in the activated sludge process are "sludge age" and "sludge quantity."
AS			18. Visual observations of pumps and meters for indicators of operational problems is applicable to troubleshooting the activated sludge treatment process.
ET			19. Troubleshooting is defined as the practice of problem solving.
TF			20. Flow and recirculation rates are useful tests for troubleshooting trickling filters.

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	TRUE	FALSE	
SH			21. Troubleshooting problems with anaerobic digestion should include a study of piping, pumping, heating and process controls.
OV			22. According to a national survey of treatment facilities, more than half of secondary facilities are meeting secondary effluent requirements.
LT			23. The troubleshooter may need to analyze sludge content in problems involving land treatment.
OV			24. A plant which has recently received an NPDES permit will not require troubleshooting.
MB			25. With a knowledge of management systems, troubleshooters should be able to provide assistance to the operator and/or plant superintendent.
AS			26. A white foam on the aeration tank surface usually indicates a young sludge and high solids.
LP			27. It is important for the troubleshooter to distinguish between various uses of a plant lab.
PT			28. The troubleshooter should recommend operating mechanical scrapers less frequently to correct a "floating sludge" problem.
TF			29. Part-time operators are usually less effective because they are too busy to care about plant operations.

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	TRUE	FALSE	
CA			30. To control periodic pollutant overloads the troubleshooter may wish to recommend the use of coagulants.
ET			31. The troubleshooter should personally try to maintain control over plant operations.
MB			32. Obvious "dry labbing" is an indicator of management problems.
CH			33. Ozone, lime and powdered potassium are good alternatives to chlorine for odor control.
AS			34. Since no two activated sludge systems are alike, skill in troubleshooting activated sludge plants is best achieved through experience.
SH			35. In addition to anaerobic digestion, the only type of solids handling processes are gravity thickening, sludge drying beds and vacuum filtration.
LT			36. For above ground surface lines, electro-chemical corrosion should be corrected with plastic pipe.
AS			37. Before effective troubleshooting of activated sludge plants can begin, operating and design data should be analyzed.
AS			38. Organic overload and toxics are causes of high BOD and/or suspended solids which can be controlled by the troubleshooter.
LP			39. Hydrogen sulfate (H_2SO_4) should be used as a preservative for samples containing metals.

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	TRUE	FALSE	
FM			40. In flow measurement, the three types of "constrictores" are: a) flumes, b) pumps and c) weirs.
OL			41. One of the characteristics of an aerated lagoon is that it requires a depth of between 10 and 20 feet.
SH			42. Sludge drying beds are probably used more than any other method of sludge dewatering.
CA			43. Chemical coagulants are less difficult to troubleshoot than conventional operations.
MB			44. The troubleshooter should not hesitate to serve as a management consultant when he observes plant management problems.
OV			45. Troubleshooters generally need not be concerned with "marginal performers" since new construction should be recommended.
TF			46. Land renovation areas usually have minor problems and little or no soil erosion problems.
LT			47. "Upgrading" a trickling filter plant means to increase its size.
AS			48. Sludge bulking is usually created from biological causes.
PT			49. A jar test is an acceptable method for determining dissolved oxygen in the primary treatment process.

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	TRUE	FALSE	
CH			50. Because chlorine is a colorless, hard-to-detect gas, a gas mask should always be kept inside the chlorine room.
OV			51. The troubleshooter should generally avoid discussing plant problems with various plant personnel.
ET			52. Assuring the plant operator of your expertise about his plant is an important first step.
OL			53. Normally, the expected performance of oxidation lagoons won't meet secondary effluent requirements.
SH			54. High drum speed, high feed rate, and low vacuum are typical causes of "thin cake" problems when troubleshooting vacuum filters.
AS			55. An activated sludge "package plant" is defined as a self-contained plant that can be transported to a site and handle flows for approximately 50,000 people.

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PART III. Indicate for the following problem HOW you would apply the troubleshooting process to solve it. Use the remainder of this sheet to explain HOW you would proceed. (25 points)

1. You are informed that a treatment facility, using two faculative oxidation lagoons in series for secondary treatment, has been operating sporadically with highly variable results. The lagoons, which can be operated both in series and in parallel, have a depth of 4 feet, total capacity of 150,000 gpd, a deep green color, and no industrial waste. You are asked for your recommendations for improving the performance of this plant.

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ANSWER KEY

PART I:

1. Analyze and learn
    - a. begin troubleshooting
    - b. review information
    - c. visit plant: meet and listen, observe & review
    - d. determine data needs
    - e. analyze: sample, test and analyze
    - f. process test: modify process and analyze
2. Formulate alternative solutions
    - a. initial opinion
    - b. opinion (learning more)
    - c. alternatives
    - d. prioritized alternatives
    - e. confirm opinions (satisfied?)
3. Corrective actions: trial & error
    - a. corrective action
    - b. get outside help? (experts, your boss, references)
4. Observe & test
    - a. desired results and effects?
5. Long range implementation
    - a. chemical additions, cleaning & maintenance, management changes, design modifications, flow changes, equipment repaired and replaced
    - b. monitor results
    - c. document & follow up

PART II:

1. F
2. F
3. F
4. F
5. F
6. T
7. T
8. T
9. F
10. F
11. T
12. T
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43. F
44. F
45. F
46. F
47. F
48. F
49. F
50. F
51. F
52. F
53. T
54. F
55. F

CLOSING

LESSON PLAN – SUBDIVISION 2 **TIME: 15 MINUTES**

Title: Summary of Course

Instructor Objectives: To briefly review the course content and approach in a concise summary the Process of Troubleshooting as applied to operational problems at wastewater treatment plants.

Student Objectives: As a result of this lesson subdivision, students will be able to do the following:

1. Summarize the purpose and content of the course, and relate in a brief manner the concepts of the Process of Troubleshooting to operational problems in wastewater treatment plants.

Training Materials:

Course Objectives, Student Notebook Page OV-2

Notes on Troubleshooter Behavior, Student Notebook page TT-1

Process of Troubleshooting Chart

Classroom Set-up:

A normal classroom set-up will be required. Students should be seated with their student groups.

Chalkboard or easel

Pointer

Subdivision Schedule:

Within the 15 minute time period, the following schedule should be followed:

TIME	SUBJECT
0 – 5 Minutes	Purpose and Objectives of Course
5 – 10 Minutes	The Process of Troubleshooting
10 – 15 Minutes	Review of Lesson Subjects

Subdivision Approach:

The instructor is to briefly cover the review material provided in the lesson plan outline. The instructor's approach should be to "tie the pieces" of the course together, by touching on the purposes, the Process of Troubleshooting, and the technical content of the course.

Student input and comments should be sought.

LESSON OUTLINE

I. Purpose and Objectives of Course (5 Minutes)

A. Review with the class, briefly, the course objectives, as provided in Student Notebook page OV 1-7

B. Review with class, the intended level of accomplishment "At the completion of this course, students will be able to," Student Notebook page OV 1-7

C. Discuss briefly the fact that the content of all the intervening lessons was designed to meet the stated objectives, and, depending on how well you've done in presenting the course you believe that the students are now able to perform their job functions in a manner such that they will meet the intended level of accomplishment resulting from the course

D. Briefly call for comments and discussion on the course objectives

II. The Process of Troubleshooting (5 minutes)

A. Review the Process of Troubleshooting noting that it provided the thread that linked the various lessons and components of the course

B. Using Notebook page ET-1, review the following:

1. Definition of Troubleshooting:
2. Troubleshooting is a Process Which:
3. Troubleshooting Goals Include:
4. Troubleshooters are:
5. Characteristics of Good Troubleshooter Behavior:

C. Briefly call for comments and discussion relating to the Process of Troubleshooting

KEY POINTS & INSTRUCTOR GUIDE

Guide: The Course Director or Instructor should review the objectives of the course as a means of summarizing, and seeing whether or not the course has accomplished its purpose.

Key Point: Students completing this course should be more effective at troubleshooting and providing technical assistance.

Refer class to Process of Troubleshooting Chart.

Refer class to Student Notebook page ET-1, Notes on Troubleshooter Behavior.

Key Point: Stress the value of human skills in Troubleshooting.

LESSON OUTLINE

III. Review of Lesson Subjects (5 minutes)

  A. Elements of Troubleshooting

    1. Human attitudes and behavior in troubleshooting
    2. The importance of a systematic approach

  B. Pre/Primary Treatment

    1. The importance of pretreatment to overall plant performance
    2. The value of visual observations and lab tests

  C. Trickling Filters

    1. Understanding the basic properties and expected performance of a treatment process
    2. Special problems in dealing with small plants

  D. Oxidation Lagoons

    1. Application of the systematic process of troubleshooting to solving plant problems
    2. The opportunity for "creative troubleshooting" solving problems with a "hands-on" approach

  E. Laboratory Practices

    1. The value of the lab in process control and in troubleshooting plant problems

  F. Flow Measurement

    1. The importance of gauging plant flows as a key to understanding plant operation

  G. Chemical Additions

    1. Factors considered in applying chemicals, and the consequences
    2. Importance of understanding expected plant performance before troubleshooting

KEY POINTS & INSTRUCTOR GUIDE

Guide: It is not possible to thoroughly review the content of each lesson. The outline provides one or two Key Points associated with each lesson, which the instructor can touch on as a summary to the course.

LESSON OUTLINE

H. Management Behavior
   1. The importance of management as a key to plant operations
   2. The use of management systems on a treatment plant

I. Activated Sludge
   1. Process control concepts
   2. Use of the Process of Troubleshooting to solve problems

J. Solids Handling
   1. Communications problem between engineers and operators
   2. Plant failure due to improper solids handling

K. Land Treatment
   1. Similarity of land application of sludge and effluent

L. Chlorination
   1. Applicability of chlorine to a variety of plant uses
   2. Troubleshooter must know the properties and hazards of chlorine

KEY POINTS & INSTRUCTOR GUIDE

Guide: If any time remains, call for questions or discussion.

CLOSING

LESSON PLAN – SUBDIVISION 3 (OPTIONAL) **TIME: 30 MINUTES**

Title: Evaluation and Critique

Instructor Objectives: To receive an objective written (anonymous) evaluation of the course, and to provide an opportunity for open verbal discussion and critique.

Training Materials:

Written evaluation form, prepared by the Course Director, to provide the students with an opportunity to render a thorough evaluation of the course.

Classroom Set-up:

A normal classroom set-up will be required

Subdivision Schedule:

Within this optional 30 minute subdivision, there are two possible 15 minute segments.

TIME	ACTIVITY
0 – 15 Minutes	Written Evaluation of the Course
15 – 30 Minutes	Verbal Critique of Course

Subdivision Approach:

This subdivision should be included only if written and verbal feedback on the course is desired. If so, it can be done as follows:

Written Evaluations: Utilize a prepared written evaluation form that calls for student evaluation of the course. This can be done anonymously. The forms should allow for a rating or evaluation of *each* lesson segment, calling for an evaluation of the following aspects of each lesson:

Subject and content

Training materials

Instructor

Overall approach

In addition, the forms should provide some room for comments on the course as a whole. A written evaluation can be particularly valuable if you are planning on presenting the course more than one time.

Verbal Critique: The course director may lead a 15 minute discussion critiquing the course. Often this has the beneficial effect of having students learn the viewpoints of their fellow students, and then feel more positive toward contributing their own views. The critique discussion may be critical if criticism is due, so long as it is constructive.

During a verbal critique, the Course Director should not take a defensive posture. However, he may offer explanation as to why certain things were done the way they were.

CLOSING

LESSON PLAN – SUBDIVISION 4 TIME: 15 MINUTES

Title: Awarding of Certificates – Student Recognition

Instructor Objectives: To recognize the student completion of the Troubleshooting Course.

Training Materials:

Certificates, if available, or other documents recognizing student participation in the course

Subdivision Approach:

1. Course Director should say a word of appreciation for the students who participated (and for the faculty, persons who handled arrangements, etc)
2. Thank students for their attentiveness, cooperation, interest, etc
3. Award certificates individually, to each student, by calling out their names, handing them the correct certificate, and offering a word of congratulations

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